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REMOVAL SUPPORT TEAM 3
EPA CONTRACT EP-S2-14-01

July 17, 2015

Mr. Eric Daly, On-Scene Coordinator
U.S. Environmental Protection Agency
Response & Prevention Branch
2890 Woodbridge Avenue
Edison, NJ 08837

EPA CONTRACT NO: EP-S2-14-01
TDD NO: 0006-0061
DOCUMENT CONTROL NO: RST3-02-D-0015
SUBJECT: DRAFT RADIOLOGICAL SURVEY WORK PLAN - NIAGARA FALLS BOULEVARD RADIOLOGICAL SITE, NIAGARA FALLS, NIAGARA COUNTY, NEW YORK

Dear Mr. Daly,

Enclosed please find the Draft Radiological Survey Work Plan for the survey activities to be conducted at the Niagara Falls Boulevard Radiological Site located in Niagara Falls, Niagara County, New York, beginning on July 20, 2015. If you have any questions or comments, please do not hesitate to contact me at (732) 585-4413.

Sincerely,

Weston Solutions, Inc.

Bernard Nwosu
RST 3 Project Manager

Enclosure
cc: TDD File No.: 0006-0061

DRAFT RADIOLOGICAL SURVEY WORK PLAN

SITE NAME: Niagara Falls Boulevard Radiological Site
DC No.: RST3-02-D-0015
TDD No.: 0006-0061
CERCLIS ID: NYN000206699
EPA ID: A23Q
EVENT DATES: July 20 through 24, 2015

SITE LOCATION: 9524 & 9540 Niagara Falls Boulevard
Niagara Falls, Niagara Falls County, New York

1.0 Historical/Current Site Information

The Niagara Falls Boulevard Radiological Site (the S ite), is located in a mixed commercial and residential area of Niagara Falls, New York. The site consists of two parcels, namely 9524 and 9540 Niagara Falls Boulevard. This site encompasses approximately 2.53 acres. Currently, the 9524 Niagara Falls Boulevard property contains a bowling alley and an asphalt parking lot; the 9540 Niagara Falls Boulevard property contains a vacant building and an asphalt parking lot. The properties are bordered to the north by a wooded area; to the east by a church; to the south by Niagara Falls Boulevard, beyond which is a residential area; and to the west by a hotel and residential area.

In 1978, the U.S. Department of Energy conducted an aerial radiological survey of the Niagara Falls region and found more than 15 properties having elevated levels of radiation above background levels. It is believed that, in the early 1960s, slag from the Union Carbide facility located on 47th Street in Niagara Falls was used as fill on the properties prior to paving. The Union Carbide facility processed ore containing naturally-occurring high levels of uranium and thorium to extract niobium. The slag contained sufficient quantities of uranium and thorium to be classified as a licensable radioactive source material. Union Carbide subsequently obtained a license from the Atomic Energy Commission, now the Nuclear Regulatory Commission, and the State of New York; however, the slag had been used as fill throughout the Niagara Falls region prior to licensing. Based on the original survey and subsequent investigations, it is believed that the radioactive Union Carbide slag was deposited on the Site.

In September/October 2006 and May 2007, the New York State Department of Environmental Conservation (NYSDEC) conducted radiological surveys of the interior and exterior of both properties on several occasions using both Exploranium-135 and Ludlum Model 2221 detectors. With the exception of an office area and storage space at 9540 Niagara Falls Boulevard that wa s constructed after the original building directly on top of the asphalt parking lot, interior radiation levels were relatively low. The highest reading in the newer area was 115 microroentgen per hour (μR/hr); elsewhere throughout the building, radiation levels generally ranged between 10 and 20 μR/ hr. Exterior readings taken at waist height generally ranged between 10 and 350 μR/hr, while the maximum reading of 600 μR/hr was recorded on contact (i.e., at the ground surface). At a fenced area behind the building located at 9540 Niagara Falls Boulevard, waist-

HIGH READINGS RANGED BETWEEN 200 AND 450 MR/HR, AND ON-contact readings ranged between 450 and 750 μR/hr. Elevated readings were also observed on the swath of grass between the 9524 Niagara Falls Boulevard property and the adjacent property to the west that contains a hotel, and in the marshy area beyond the parking lot behind the buildings. Two biased samples of slag were collected from locations that exhibited elevated static Ludlum detector readings: one sample was collected from an area of loose blacktop that indicated readings of 515,905 counts per minute (cpm) on the Ludlum detector, and one slag sample was collected in the marshy area that indicated readings of 728,235 cpm on the Ludlum detector.

During a reconnaissance performed by the New York State Department of Health (NYSDOH) and NYSDEC on July 9, 2013, screening activities showed radiation levels at 200 μR/hr with a hand-held pressurized ion chamber (PIC) unit around an area of broken asphalt and 500 μR/hr from a soil pile containing slag at the Site. Readings over 600,000 cpm were recorded with a sodium iodide 2x2 scintillation detector from the soil and slag pile.

On September 10, 2013, Weston Solutions Inc., Site Assessment Team (SAT) conducted a gamma radiation screening of the 9524 Niagara Falls Boulevard property using a Ludlum Model 2221 Scaler Ratemeter. On December 4–5, 2013, further radiological survey information was obtained from the 9524 and 9540 Niagara Falls Boulevard properties, as well as the church property located further east of the two site parcels. The highest gamma radiation screening results were recorded from the exposed soil area in the rear, northern portion of the 9540 Niagara Falls Boulevard property.

From December 5 through 7, 2013, SAT documented the areas of observed contamination at the Site. The areas of observed contamination were delineated by measuring the gamma radiation exposure rates, and determining where the gamma radiation exposure rate around the source equals or exceeds two times the gamma radiation at site-specific background rates. The areas of observed contamination are defined by site-attributable gamma radiation exposure rates, as measured by a survey instrument held 1 meter above the ground surface, which equal or exceed two times the site-specific background gamma radiation exposure rate. At Site, an area of approximately 168,832 square feet was found to have gamma radiation levels which exceed two times the background measurement of 8,391 cpm. PIC data were also collected at several points to confirm the boundary.

On December 11, 2013, SAT collected a total of 16 soil samples (including one environmental duplicate sample) and three slag samples from fifteen boreholes advanced throughout the Site and the First Assembly Church property located directly adjacent to the east/northeast of the Site property, using hollow-stem auger drilling methods. The two soil samples collected on the First Assembly Church property were to document background conditions. At each sample location, soil samples were collected directly beneath slag; at locations where slag was not present, the soil sample was collected at the equivalent depth interval. The soil samples were analyzed for target analyte list (TAL) metals, isotopic thorium, isotopic uranium, radium-226, radium-228 by alpha spectroscopy; and radioisotopes by gamma spectroscopy. The slag samples were analyzed for isotopic thorium, isotopic uranium, radium-226, radium-228 by alpha spectroscopy; and radioisotopes by gamma spectroscopy. Analytical results indicated concentrations of

radionuclides found in the slag and soil to be significantly higher than at background conditions (i.e., greater than 2x background concentrations).
On April 28, 2014, U.S. Environmental Protection Agency (EPA) contractor personnel collected radon and thoron concentration measurements from locations on and in the vicinity of the Site. At the selected locations in background areas, above the source material, and off the source area, radon and thoron concentration measurements in picocuries per liter (pCi/L) were collected with RAD7 radon detectors. The radon and thoron measurements were collected at heights of one meter above the ground surface. The measurements included uncertainty values, which were taken into account to calculate adjusted concentrations for evaluation of observed release in the air migration pathway. There were no radon or thoron concentrations that exceeded the site-specific background, nor were there any adjusted concentrations that equaled or exceeded a value two standard deviations above the mean site-specific background concentration for that radionuclide in that type of sample (i.e., there is no evidence of an observed release to air from site sources).

2.0 RST 3 Scope of Work

Weston Solutions, Inc., Removal Support Team 3 (RST 3) has been tasked by EPA to provide support for radiation surveying to be conducted at the Site. Gamma radiation surveys will b e conducted with the use of a Fluke PIC and a Ludlum Model 2241 gamma survey meters. Radon and thoron gas will be measured using a Durridge RAD7 radon detector. Specific isotopes will be identifie d using a Berkeley Nucleonics Corporation (BNC) SAM 940 ™ portable, radio-isotope identification system. The surveying locations will be determined on-site by the EPA On-Scene Coordinator (OSC).

3.0 Radiological Survey Instruments Work Statement

3.1 Ludlum Model 2241 : This instrument will be used to perform gross gamma survey. A sodium iodide gamma scintillator will be attached to the unit and held approximately 6 inches above the ground when collecting measurements. A mobile survey which will require the user to walk the Site along pre-determined paths will be performed. The highest and lowest readings from the Ludlum will be recorded for approximately 60 seconds in cpm. Refer to Attachment B: Ludlum Model 2241 Survey Meter Operators Manual.

3.2 Fluke Pressurized Ionization Chamber (PIC): Two measurements from the PIC will be recorded at each location surveyed; one at contact (1 inch above the ground) and one at waist height (1 meter/3 feet above the ground). Survey time for each reading will be at least 30 seconds depending on the settling of the value. Data will be collected within a 5 by 5 foot grid in the areas of concern (AOCs). All the results obtained from the PIC measurements will be recorded as a range (e.g. 4-6 μR/hr). If very low level gamma levels are observed, a Reuter Stokes RSS-131ER Pressure Ion Chamber will be utilized to determine the exact levels. Refer to Attachment C: Fluke 451P Ion Chamber Survey Meter Operators Manual.

3.3 Durridge RAD7: Two air sampling measurements will be collected at each location, one at waist height (1 meter/3 feet above the ground) and one at contact (1 inch above the ground). The waist sampling location will always be collected prior to the contact location. Sampling will begin at areas with the lowest known concentrations of radiation, as determined by measurements collected with the PIC and Ludlum Model 2241. Refer to Attachment D: Durridge RAD7 Radon Detector User Manual.

3.4 BNC SAM 940 ™: This instrumentation will be used to identify isotopes. The instrumentation will be used in specific areas that have elevated gamma radiation, as determined by the surveys conducted with the gamma survey meters. Refer to Attachment E: BNC Model 940 SAM Eagle+™ Instruction Manual.

4.0 Considerations Relative to Thoron and Radon Sampling

Uranium (half-life of 4.5 billion years) is a naturally occurring radioactive isotope, decaying primarily by alpha emission with accompanying gamma radiation. Uranium produces several radioactive isotopes including radium-226 (Ra-226) and radon-222 (Rn-222), which have a half-life of 1,602 years and 3.8 days, respectively. Rn-222 is a radioactive isotope which naturally forms as a gas, producing several radioactive radon decay products, including polonium-218, lead-214, bismuth-214 and polonium-214.

Thorium (half-life of 14 billion years) is a naturally occurring radioactive isotope, decaying primarily by alpha emissions with accompanying gamma radiation. Thorium produces several radioactive isotopes, including gamma emitting actinium-228 (Ac-228), lead-212 (Pb-212), bismuth-212 (Bi-212), radium-224 (Ra-224) and gas thoron-220 (Rn-220). Ra-224 and Rn-220 have a half-life of 3.6 days and 55 seconds, respectively.

Radon (Rn-222) and thoron (Rn-220) concentrations in ambient air can vary widely on both a seasonal and diurnal basis. On a seasonal basis, the highest concentrations are observed during the winter, and the lowest concentrations observed during the summer. On a daily basis, the highest concentrations are typically observed in the early morning, and the lowest at noon. This variability is due to changes in the emanation or flux rates, atmospheric conditions which dilute the concentration of these radionuclides, and radioactive decay.

The flux rate is the rate at which these noble gases emanate from their particulate matrices into pore spaces, diffuse through the soil pore spaces, and then escape from the ground into the air. Conditions which can impact the flux rate include soil moisture, standing water, barometric pressure, soil grain size, and soil compaction.

Atmospheric conditions that impact the concentration of these radionuclides include air turbulence that changes with air temperature and wind speed, ground surface characteristics such as slopes and ravines that allow these heavier-than-air gases to accumulate at higher concentrations in low-lying areas, and elevation above the ground surface at which measurements are made.

The elevation of the sampling point may impact the measured thoron concentration. In addition, the very short half-life of thoron significantly limits the distance the thoron can travel from its emanation point before it decays to a particulate radionuclide that will diffuse no further and remains in the solid matrix. Assuming a wind speed of 5 miles per hour (mph), equivalent to 440 feet per second (fps), and assuming that the thoron emanated into the air at the instant of its formation from thorium-232, the gas would be at 50 percent (%) of its initial concentration due to radioactive decay at approximately 410 feet from its origin.

5.0 Thoron and Radon Background Concentrations

Radon concentrations in uncontaminated or non-impacted areas have been known to vary by a factor of approximately four ranging from 0.1 pCi/L to 0.4pCi/L, and thoron concentrations have been known to vary by an order of magnitude, from 0.05 pCi/L to 0.5 pCi/L (*UNSCEAR 1982, "Ionizing Radiation: Sources and Biological Effects", Annex D: Exposure to Radon and Thoron and Their Decay Products*).

As part of the current radiological survey design, RST 3 will collect background readings from a minimum of one of the background locations that will be selected by the EPA OSC per each RAD7 instrument being utilized for the investigation in order to document any deviation in background concentrations for each of the RAD7 instruments.

6.0 Work Statement for Thoron and Radon Survey

A defensible sampling plan for environmental monitoring of radon and thoron concentrations in outdoor locations must account for the following factors:

- How the gases are generated, released to the atmosphere, and dispersed/diluted in air;
- How long their particulate decay products persist as determined by their half-lives;
- How environmental conditions, such as humidity and temperature, affect the measurements and whether correction factors may be applied to the data;
- How the measurement device should be set up, operated, and maintained to collect the desired data;
- How the data will be collected, saved, manipulated, and reported to meet the project objectives; and
- At what elevation will the thoron concentration be sampled.

The data are not intended to quantify or account for the significant diurnal variations of these isotopes' concentrations, nor to determine if the locations are impacted by releases from the Site.

The following information addresses these factors as they apply to using the Durridge RAD7 detector to monitor the maximum number of locations around the Site over a predetermined period, to acquire data with reasonable sensitivity levels, and to provide baseline values from short-term measurements at each location.

The RAD7 instrument will measure and report concentrations of radon and thoron simultaneously. It can be operated in any of three modes, depending on the conditions and objectives. The accuracy of its measurements depends primarily on the counting statistics as determined by the sample period for each measurement. Environmental concentrations are expected to be in the lowest range (*i.e,* 1 pCi/L), and the maximum sample period possible while ensuring that instruments are attended to by operators to ensure the security of the machines and quality of the data is for approximately 8 hours. The reported uncertainty at 1 pCi/L for radon-222 for a 4 hour sample period is approximately 0.21 pCi/L (21%). At lower concentrations, the uncertainty will be larger.

The instrument precision will be affected, although to a much lower degree, by humidity and temperature factors. Both can be minimized by applying applicable correction factors to the final data. As a result, temperature and humidity data should be measured and recorded hourly during each sample period. Desiccant will be applied at the sample inlet to remove moisture from the sample and prevent it from entering the RAD7. The 6-inch long desiccant drying tube will be used and may be changed out mid-sampling by pausing the RAD7. The 6-inch de siccant drying tube will be used because this is the setup used during factory calibration. In all cases, the sampled air will flow through a 6-inch long drying tube filled with desiccant, through a 3-foot long vinyl hose, through an inlet particulate filter, and into the RAD7 detector.

Air samples will be collected over a 4 hour period from each location specified by the EPA OSC. If rain is encountered during the sampling period the RAD7 will be turned off and protected from the rain until weather conditions improve. In these cases, a sampling period of less than 4 hours may be used. The minimum acceptable sampling period at each location will be 3 hours.

Atmospheric and soil moisture conditions will be recorded for each sampling period. Atmospheric measurements will include wind speed and direction and barometric pressure from the nearest weather station. If rain has occurred within the past 24 hours an estimate of the rainfall amount will be recorded. Any standing water or an estimate of the soil moisture condition will be noted on the field data sheet. Refer to Attachment A: Radon/Thoron Field Data Sheet.

The RAD7 must be operated in THORON mode in order to log concentrations of both radon and thoron. Each instrument will be purged following the end of the sample period and before a new sampling period to minimize the concentration of trapped particles.

Data should be downloaded from each instrument at the end of each sample period, and batteries charged if the battery voltage is 6.0 volts or below.

7.0 RAD7 Instrumentation Setup and Sampling Procedure:

The RAD7 instrumentation setup and sampling procedure will be as follows:

- The RAD7 will be purged for a period of ten minutes at a location that is known to have 1 pCi/L or less of either radon-220 or radon-222 before each sampling period.

- The RAD7 will be established at one of the locations specified on the map provided in the Interagency Draft Proposed Sampling Plan for Thoron-220 Gas Measurements and Gamma Exposure Surveys based on the sampling schedule developed by RST 3.
- The instrument will be programmed with the following settings: Protocol – User, Cycle – 01:00, Recycle – 4, Mode – Auto, Thoron – On, Pump – Auto, Tone – Geiger, Format – Short, and Units – pCi/l and °C; whereas the instrument will be set to record a measurement for radon-220 and radon-222 once an hour for a period of four hours. The printer will give a real-time read out of the measurements every hour and will also store the data on the unit for download after the test is complete.
- A tripod will be used to set the sample inlet 3-feet above the ground surface. The sample will flow through a 6-inch long drying tube filled with desiccant, through a 3-foot long vinyl hose, through an inlet particulate filter, and into the RAD7 instrument.
- The instrument will automatically run for a 4 hour period. The sampler will pause the run to change out the desiccant as needed. The sampler will also pause the run if there is any precipitation. If precipitation is heavy and consistent, the run will be terminated.
- The following information will be recorded on the field data sheet (refer to Attachment B, Field Data Sheet) for each sampling location at the beginning of sampling: RAD7 serial number, location ID, location cross streets and descriptions, date, the sampler's name, current date and time, user settings (current date and time, protocol, cycle, recycle, mode, and thoron on/off), and initial weather (*i.e.,* cloud coverage, temperature, wind direction, wind speed, UV index, dew point, humidity, and pressure). All weather information will be gathered using the Weather Channel application for the iPhone which will be set for Ridgewood, Queens, New York. Variations in what the application presents and what the sampler can visually assess, such as cloud cover, will be noted.
- The following information will be recorded on the field data sheet every hour: weather from the Weather Channel application, weather from the RAD7 print out (temperature and relative humidity), radon-220 reading, and radon-222 reading.
- Anytime that the desiccant tube needs to be changed, the time will be recorded on the Field Data Sheet.
- At the end of the run, the data will be downloaded for that run and the instrument will be purged for 10 minutes (if the readings for radon-220 and radon-222 at the current location were below 1 pCi/L) before moving to the next location.

Attachment A

Radon/Thoron Field Measurement Data Sheet

U.S. Environmental Protection Agency, Region II
Weston Solutions, Inc., Removal Support Team 3
Radon/Thoron Field Measurement Data Sheet

RAD7 Serial Number:	**Site Information**	**Date:**
RAD7 Model #:		**Start Time:**
RAD7 Calibration date:		**Stop Time:**
Location ID:	**Site Name:** Niagara Falls Boulevard Radiological Site	**RST 3 Sampler**
Location/Cross Streets/Description:	**Site Address:** 9524 & 9540 Niagara Falls Boulevard Niagara Falls, Niagara Falls County, New York	**Sampler Signature:**

Initial Run Info	
Date/Time:	Thoron: ON
Protocol: USER	Pump: AUTO
Cycle: 01:00	Tone: GEIGER
Recycle: 4	Format: Short
Mode: AUTO	Rad/Temp Units: pCi/L / ^{o}C

Starting Weather	
Cloud Coverage:	UV Index:
Temperature:	Dew Point:
Wind Direction:	Humidity:
Wind Speed:	Pressure:
Comments:	

Information after 1 Hour

Weather from App:	
Cloud Coverage:	UV Index:
Temperature:	Dew Point:
Wind Direction:	Humidity:
Wind Speed:	Pressure:

Measurements from RAD7 Print Out:	
Radon (Sniff) Measurement:	Thoron Measurement:
Temperature:	Relative Humidity:

Information after 2 Hours

Weather from App:	
Cloud Coverage:	UV Index:
Temperature:	Dew Point:
Wind Direction:	Humidity:
Wind Speed:	Pressure:

Measurements from RAD7 Print Out:	
Radon (Sniff) Measurement:	Thoron Measurement:
Temperature:	Relative Humidity:

Information after 3 Hours

Weather from App:	
Cloud Coverage:	UV Index:
Temperature:	Dew Point:
Wind Direction:	Humidity:
Wind Speed:	Pressure:

Measurements from RAD7 Print Out:	
Radon (Sniff) Measurement:	Thoron Measurement:
Temperature:	Relative Humidity:

Information after 4 Hours

Weather from App:	
Cloud Coverage:	UV Index:
Temperature:	Dew Point:
Wind Direction:	Humidity:
Wind Speed:	Pressure:

Measurements from RAD7 Print Out:	
Radon (Sniff) Measurement:	Thoron Measurement:
Temperature:	Relative Humidity:

Tube Change Times:

Comments:

U.S. Environmental Protection Agency, Region II
Weston Solutions, Inc., Removal Support Team 3
Radon/Thoron Field Measurement Data Sheet

The RAD7 instrumentation setup and sampling procedure

The RAD7 will be purged for a period of ten minutes at a location that is known to have 1 pCi/L or less of either radon-220 or radon-222 before each sampling period.

The RAD7 will be established at one of the locations specified on the map provided in the Interagency Draft Proposed Sampling Plan for Thoron-220 Gas Measurements and Gamma Exposure Surveys based on the sampling schedule developed by RST 3.

The instrument will be programmed with the following settings: Protocol – User, Cycle – 01:00, Recycle – 4, Mode – Auto, Thoron – On, Pump – Auto, Tone – Geiger, Format – Short, and Units – pCi/l and °C; whereas the instrument will be set to record a measurement for radon-220 and radon-222 once an hour for a period of four hours. The printer will give a real-time read out of the measurements every hour and will also store the data on the unit for download after the test is complete.

A tripod will be used to set the sample inlet 3-feet above the ground surface. The sample will flow through a 6-inch long drying tube filled with desiccant, through a 3-foot long vinyl hose, through an inlet particulate filter, and into the RAD7 instrument.

The instrument will automatically run for a 4 hour period. The sampler will pause the run to change out the desiccant as needed. The sampler will also pause the run if there is any precipitation. If precipitation is heavy and consistent, the run will be terminated.

The following information will be recorded on the field data sheet (refer to Attachment B, Field Data Sheet) for each sampling location at the beginning of sampling: RAD7 serial number, location ID, location cross streets and descriptions, date, the sampler's name, current date and time, user settings (current date and time, protocol, cycle, recycle, mode, and thoron on/off), and initial weather (i.e., cloud coverage, temperature, wind direction, wind speed, UV index, dew point, humidity, and pressure). All weather information will be gathered using the Weather Channel application for the iPhone which will be set for Ridgewood, Queens, New York. Variations in what the application presents and what the sampler can visually assess, such as cloud cover, will be noted.

The following information will be recorded on the field data sheet every hour: weather from the Weather Channel application, weather from the RAD7 print out (temperature and relative humidity), radon-220 reading, and radon-222 reading.

Anytime that the desiccant tube needs to be changed, the time will be recorded on the Field Data Sheet.

At the end of the run, the data will be downloaded for that run and the instrument will be purged for 10 minutes (if the readings for radon-220 and radon-222 at the current location were below 1 pCi/L) before moving to the next location.

ATTACHMENT B

Ludlum Model 2241 Survey Meter Operators Manual

LUDLUM MODEL 2241
SURVEY METER

June 2015

Serial Number 238822 and Succeeding

Serial Numbers

LUDLUM MODEL 2241
SURVEY METER

June 2015

Serial Number 238822 and Succeeding Serial Numbers

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

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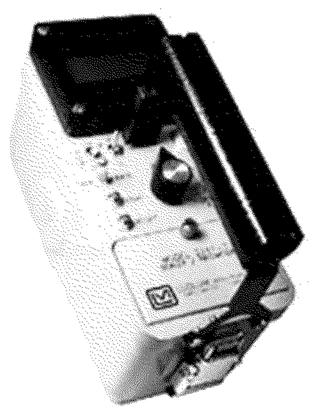
Section 1

Introduction



The Model 2241 is a portable microprocessor-based digital scaler/ ratemeter designed for use with scintillation, Geiger-Mueller (GM), and proportional type detectors to measure ionizing radiation. Data is presented on a four-digit (six digits in the Scaler mode) Liquid Crystal Display (LCD) with moving decimal point. A three-position switch labeled OFF/RATEMETER/SCALER selects the desired operating mode for the instrument.

Programmable display units (RATEMETER mode only) are represented in either R/hr, Sv/h, cpm, or cps with multipliers of micro (µ) or milli (m) for R/hr and Sv/h and kilo (k) for cpm or cps. The display units are auto-ranging, enabling the readout to display a broad range of radiation levels. The display also offers lower limit capability. For example, the display can be set to show only values that are greater than or equal to 1 µR/hr.

This instrument incorporates independent adjustable alarms for RATEMETER and SCALER operating modes. The RATEMETER mode has two alarm indicators. The first-level alarm is indicated by display of the word "ALERT" on the LCD. The second-level alarm is indicated by display of the word "ALARM" and by the emitting of a continuous audible tone. The SCALER alarm condition will also display the word "ALARM" and produce the same audible tone. Both audible alarms may be silenced (acknowledged) by depressing the RESET switch. All alarms are concurrent.

Other features include Dead Time Correction (DTC) to compensate for detector dead time; audible click-per-event with programmable 1, 10, 100, and 1000 divide-by; LCD backlight with programmable "ON" time; programmable fixed or variable response time; and count overflow visual alarm, indicating that the counting circuitry is nearing the maximum counting capability.

All of the features described above may be programmed manually using the internal switch board or by computer through the RS-232 port. Two different detector operating parameters may be stored in non-volatile memory. The switch board can be removed after entering or changing parameters to prevent tampering with setup parameters.

A regulated high-voltage power supply, set-point control adjustable from 400 to 2400 volts with detector overload detection, and adjustable discrimination levels add versatility to the instrument. This supports operation for a broad range of detectors and connecting cable lengths. All of the calibration controls are covered to prevent any inadvertent adjustments to the detector operating parameters.

The instrument is powered by two standard ″D″ cell batteries. The unit body is made of cast-and-drawn aluminum with beige powder coating, which aids in the decontamination of surfaces.

Section 2

Getting Started

Unpacking and Repacking

Remove the calibration certificates and place them in a secure location. Remove the instrument, detectors, and accessories (batteries, cable, etc.), and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 2241 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

Important!

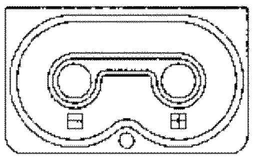
If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to a specific detector(s), and is therefore not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling.

Every returned instrument must be accompanied by an **Instrument Return Form**, which can be downloaded from the Ludlum website at www.ludlums.com. Find the form by clicking the "Support" tab and selecting "Repair and Calibration" from the drop-down menu. Then choose the appropriate Repair and calibration division where you will find a link to the form.

Battery Installation

Ensure the OFF/SCALER/RATEMETER switch is in the OFF position. Open the battery lid by turning the quarter-turn thumb screw counterclockwise.

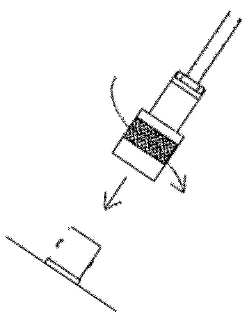


Install two "D" size batteries in the compartment. Note the (+) and (–) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid.

Note:

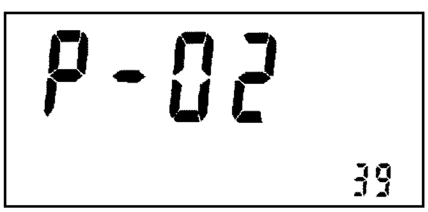
The center post of a "D" size battery is positive.

Operational Check



Connect a detector to the Model 2241 by using the cable provided; firmly pushing the connectors together while twisting clockwise until the connector latches (one-quarter turn). The diagram to the left illustrates how this is done.

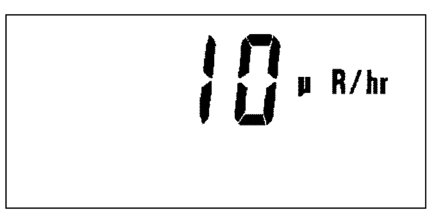
Turn the OFF/SCALER/RATEMETER switch to the RATEMETER position. Notice that the display goes through an initialization sequence. The display will show all 8s with decimal points. Check to make sure all segments display, as illustrated in the diagram to the left.



The LCD then displays the firmware number in the format "P-XX YY." The "XX" is the firmware number, and the "YY" is the firmware version. (The figure to the left is for example only; to illustrate location of display.)

The minimum displayable value (for example 00.0 µR/hr) should be shown. When switched to the SCALER position, a single 0 will be displayed.

The display will auto range to the current level (see figure at left). When auto ranging down, the Model 2241 uses multiples of 5. This technique keeps the decimal point from jumping between numbers when viewing values around multiples of 10.



Check for a proper background reading:

If using a Ludlum Model 44-9 detector, a typical reading would be 25-50 cpm or 8-15 uR/hr.

If using a Ludlum Model 44-2 detector, a typical reading would be 1.4-2.6 kcpm or 8-15 uR/hr.

A reference reading (or readings) with a check source should be obtained with the detector(s) in a constant and reproducible manner at the time of calibration or at the time the instrument is received in the field.

If at any time the instrument fails to read within 20% of the reference reading when using the same check source, it should be sent to a calibration facility for recalibration and/or repair. If desired, multiple readings may be taken at different distances and/or with different sources so that other ranges or scales are checked.

Switch the AUD ON/OFF switch to the ON position and confirm that the external unimorph speaker produces an audible click for each event detected (audio divide by 1 parameter). The AUD ON/OFF switch will silence the clicks if in the OFF position; however, an audible alarm condition will still be heard.

Increase the source activity or lower the alert and alarm points to initiate an ALERT and ALARM condition. (Refer to section 8, "Entering or Changing Switchboard Parameters.") Depress the RESET switch to acknowledge the audible alarm. Decrease the radiation activity below the ALERT and ALARM threshold and depress the RESET switch to clear the alarm conditions. If an alarm condition is not present, depressing the RESET switch the first time will reset the alert condition and zero the ratemeter.

Position a check source to produce a ratemeter reading of 100 to 2000 counts/minute or 10-100 µR/hr. While observing the ratemeter fluctuations, select between the fast and slow response time (F/S) positions to observe variations in the display. The "S" position should respond approximately five times slower than the "F" position (for fixed response mode) and three times slower when in variable response mode. The slow response position is normally used when the Model 2241 is displaying low numbers, which require a more stable display. The fast response position is used at high count levels.

Move the OFF/SCALER/RATEMETER switch to the SCALER position. Depress the COUNT switch located in the end of the carrying handle in order to initiate a count cycle. The word COUNTING should be flashing on the LCD during the count cycle and should disappear at the end of the predetermined count time. If a scaler ALARM condition occurs, the RESET switch can be depressed to acknowledge the alarm; however, the COUNT switch must be depressed to clear the visual ALARM and to restart the count cycle.

Depress and release the LIGHT switch. The backlight located behind the LCD should illuminate (for pre-programmed ON time). Select the desired F/S, AUD ON/OFF, and RATEMETER or SCALER parameters and proceed to use the instrument.

Section 3

Specifications

Instrument:

Linearity: Readings are within 10% of true value with a detector connected.

Warm-up Time: Unit may be used immediately after the LCD initialization sequence is completed (approximately five seconds after power-up).

Display: A four-digit Liquid Crystal Display (LCD) with digits one half inch in height. Two additional 0.5 cm (0.2 in.) digits are used for the overflow counter (SCALER mode) and exponential powers (parameter setup). Enunciators are provided for display units, ALERT, ALARM, low battery, detector OVERLOAD, counting OVERFLOW, and scaler COUNTING.

RATEMETER: Depending upon how the instrument was calibrated, the RATEMETER can display in either R/hr, Sv/h, cpm or cps when the control switch is in the RATEMETER position.

SCALER: activated by pushbutton in handle when the three-position switch is in the SCALER position. Count time is adjustable.

Calibration Controls: Accessible from the front of the instrument (protective cover provided). These controls are preset at the factory or calibration lab and should not be adjusted by field personnel.

> **Discriminator/Input Sensitivity**: adjustable from 2 to 100 mV; negative pulse response
>
> **Overload**: ondicated by OVERLOAD on the display; adjustable
>
> **High Voltage**: adjustable from 400-2400 volts; regulated within 0.2% at 1000 Vdc; maximum load of 50 µA

RESET: a pushbutton for zeroing the display, acknowledging and/or resetting the alarm

Note:

The RESET button only silences the alarm in the current mode that the instrument is in. For example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

LIGHT: Display backlight activated by pushbutton.

Audio: built-in audio speaker (unimorph) with AUD ON/OFF switch; greater than 60 dB at 2 feet

Alert/Alarm: indicated by either an ALERT or ALARM enunciator on the display (RATEMETER mode only) and by an audible tone

Power: two each, "D" cell batteries housed in an externally accessible sealed compartment. Current draw is approximately 35 mA with the backlight OFF. Minimum battery voltage is 2.2 ± 0.1 Vdc.

Battery Dependence: Meter readings vary by less than 3% from fully charged batteries until the battery symbol appears, indicating the need for recharge or replacement.

Battery Life: typically 200 hours with alkaline batteries (display indicates low battery condition). Instrument will operate for approximately 24 hours after the battery symbol first appears.

Size: 16.5 x 8.9 x 21.6 cm (6.5 x 3.5 x 8.5 in.) (H x W x L)

Weight: 1.6 kg (3.5 lb), including batteries

Removable Switchboard Adjustable Parameters:

Backlight "ON" Time: 5, 15, 30, 60, 90, 120, 180. or 240 seconds for the backlight to stay on when activated by the pushbutton; factory set at "5".

Set Minimum Display: allows lower limit of the auto-ranging display to be fixed. For example, the display can be set to only show values above or equal to 1 μR/hr.

RS-232 Data Dump Mode: Enables or disables dump mode to the RS-232 port ("D" type connector). When enabled, the data will be dumped every two seconds.

RS-232 Detector Setup Mode: allows for input of detector parameters via the RS-232 port

Baud Rate: selects either 150, 300, 600, 1200, 2400, 4800, 9600, or 19200 bps

Detector Dead Time Compensation (DTC): adjustable from 0 to 9999 microseconds

Calibration Constant: Adjustable from 0.001 to 280 × 10^9 counts/display unit

Display Units: can display in R/hr, Sv/h, cpm, or cps

Display Range: auto ranging from 0.0 µR/hr – 9999 R/hr; 0.000 µSv/hr – 9999 Sv/h; 0 cpm – 999 kcpm; or 0 cps – 100 kcps

Time Base: can display in seconds or minutes

Audio Divide: 1, 10, 100, or 1000 events per click

Response Time: variable or fixed ratemeter response (All stated times correspond to a range of 10% to 90% of the final reading.) Factory default is "variable" so that the instrument will automatically adjust the response time to the best setting for the current count rate.

> **Variable Response**: Dependent on the number of counts present. Typically 4 to 25 seconds for FAST, and 4 to 60 seconds for SLOW.
>
> **Fixed Response**: The parameter is adjustable from 1 to 25 resulting in a FAST response from approximately 2 to 50 seconds. The SLOW response is approximately 10 to 250 seconds. For MDA-type measurements, the fixed response mode is recommended.

Ratemeter Alert/Alarm: set at any point corresponding to the pre-selected ratemeter range

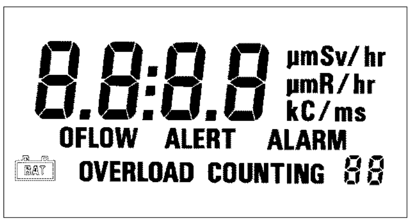
Scaler Alarm: adjustable from 1 to 999999 counts

Scaler Count Time: adjustable from 1 to 9999 seconds

Section 4

Identification of Controls and Functions

Display



The Model 2241 utilizes a four-digit liquid crystal display (LCD) with two-digit overflow (SCALER mode) and moving decimal point. The two smaller digits located in the lower right corner of the display indicate counter OVERFLOW when in the scaler counting mode (equivalent to a six-digit scaler) or exponential power when in the parameter setup mode. The upper right corner of the LCD displays units and multiplier(s) - R/hr, mR/hr, or µR/hr; Sv/h, mSv/h or µSv/h; C/m, kC/m, C/s or kC/s. The bottom part of the readout displays the ALARM, ALERT, OFLOW, OVERLOAD annunciators and the low battery icon. COUNTING indicates that the scaler mode has been initiated and is in the counting process.

Display Status Definitions

ALARM: Ratemeter or scaler count has increased above the preset alarm threshold. An audible continuous tone will accompany the "latching" ALARM condition. Depressing RESET will acknowledge the audible ratemeter and/or scaler alarm. Depressing RESET a second time will reset the ratemeter reading and ratemeter alarm. To reset the scaler ALARM, depress the COUNT switch located in the carrying handle to re-initiate the scaler count cycle.

ALERT: Ratemeter count has increased above the preset alert threshold. To reset an ALERT condition, press RESET once if in the non-alarm condition, and twice if in an alarm condition. (The first depression in the alarm condition acknowledges the audible alarm.) The ratemeter will reset to the minimum displayable reading each time the alert is reset.

OFLOW (Overflow) : RATEMETER mode - Indicates that the incoming count exceeds the capability to display stable or reliable readings corresponding to the radiation level being measured. The overflow symbol will appear when the ratemeter exceeds 100k cps or if the dead time correction is greater than 75%. OFLOW will appear in the SCALER mode when the six-digit display (four digits display and 2 overflow digits in the right corner) reaches 999999 and starts to roll over again.

OVERLOAD: indicates that the detector is being exposed to radiation intensities greater than the detector maximum operating limit. For alpha and/or beta-type scintillation detectors, an OVERLOAD may indicate that the detector face has been punctured, allowing external light to saturate the photomultiplier tube inside the detector. The overload alarm point is set by adjusting the OVL control located underneath the calibration cover.

"low battery" icon: indicates that the batteries have decreased to the minimum operating voltage of 2.2 ±0.1 Vdc. Instrument will continue to operate for approximately 24 hours thereafter.

COUNTING: indicates that the scaler count switch has been depressed and that the scaler is accumulating counts for the pre-determined count time

Front-Panel Controls

OFF/RATEMETER/SCALER Switch: a three-position rotary switch that applies power to the instrument and selects RATEMETER or SCALER counting mode.

AUD ON/OFF Switch: The clicks-per-event audio may be silenced or enabled via this front-panel toggle switch. The audible alarm is independent of the AUD ON/OFF switch and will override the audible clicks per event. An audible alarm can only be silenced by depressing the RESET button.

F/S (Fast/Slow) Response Switch: a two-position toggle switch that selects fast or slow counting response time

Variable Response: The "F" position allows the time constant (TC) to vary from 1 to 10 seconds, while the "S" position varies from 1 to 30 seconds. The response time is automatically adjusted in proportion to the incoming count rate between the "F/S" TC variables.

Fixed Response: The "F" position corresponds to the selected fixed response time - TC. The "S" position is five times slower than the selected fast TC.

LIGHT (LCD Backlight): A pushbutton switch, when depressed, illuminates the LCD for a pre-programmed time. The backlight ON time can be selected between 5 and 240 seconds during the parameter setup.

RESET Pushbutton Switch: In the non-alarm condition, depressing the RESET switch resets the ratemeter display to the minimum display readout. In an alarm condition (ratemeter or scaler), depressing RESET will silence the audible alarm. Depressing RESET a second time will reset the ratemeter alarm and/or alert condition. The scaler alarm can only be reset by depressing the scaler COUNT switch located in the end of the Model 2241 handle.

Note:

The RESET button only silences the alarm in the current mode that the instrument is in, for example, the RESET button will not affect the **scaler** alarm if the instrument is in the **ratemeter** mode.

Scaler COUNT Switch: Pushbutton switch located in the end of the Model 2241 carrying handle which, when depressed, initializes the start of the scaler count accumulation for the preset scaling time. The SCALER/RATEMETER switch must be in the SCALER position to initiate the counting cycle. The scaler display uses the two digits in the lower right-hand corner for the two most significant digits of the six-digit readout. Scaling time can be set from 1 to 9999 seconds in the parameter setup by way of the switch board. Depressing the COUNT switch after a scaler ALARM will reset the scaler display to 0, resetting the alarm condition.

Front-Panel Calibration Controls

Note:

Remove the front-panel calibration cover to expose the following calibration controls:

DISC (Discriminator): a multi-turn potentiometer (approximately 20 revolutions), used to vary the detector pulse-counting threshold from 2 to 100 millivolts. A Ludlum Model 500 Pulser or equivalent should be used in checking or adjusting the pulse discrimination parameter.

Note:

When making adjustments to the HV potentiometer, make note of the following precautions: Use a Ludlum Model 500 Pulser or high-impedance voltmeter with a high-voltage probe to measure the high voltage at the detector connector. If a Ludlum Model 500 Pulser is not available, ensure that the impedance of voltmeter used is 1000 megohms or greater.

HV: a multi-turn potentiometer (approximately 20 revolutions) that varies the detector voltage from 400 to 2400 volts. The maximum high voltage output is adjusted by the HV LIMIT potentiometer located on the internal main board.

OVL (Detector Overload): A multi-turn potentiometer (approximately 20 revolutions) that adjusts the detector current level that must be exceeded to initiate an OVERLOAD alarm. This control adjusts the current level discrimination point from 0.5 and 40 microamperes, corresponding to the specific detector saturation point.

Main Board Controls

Note:

To access the internal circuit boards, unlatch the latches at each end of the Model 2241. Carefully separate the top chassis from the bottom cover (referred to as a "can"). The can has the audio speaker (unimorph) with a two-conductor cable attached to the main board. The audio plug may be disconnected during the internal control adjustments.

HV LIMIT (R027): A multi-turn potentiometer (approximately 20 revolutions) sets the maximum HV limit with the front-panel HV control adjusted to the maximum clockwise position. It is adjustable from 1250 to 2400 Vdc.

VOLUME (R002): A multi-turn potentiometer (approximately 20 revolutions) varies the audible click-per-event and alarm audio. Adjust the control to the maximum clockwise position for maximum volume. If the VOLUME control is adjusted to the maximum counterclockwise position the clicks-per-event or the audible alarm(s) will not be audible when active.

Switch Board Controls

The switch board utilizes a 16-position rotary switch (FUNCTION) to select the 16 setup parameters. (Refer to schematics and component layout drawing near the end of the manual.) All of the setup parameters are stored in the non-volatile EEPROM, which will retain data even after the Model 2241 batteries are removed. After the parameters are entered, the switch board can be removed and the Model 2241 will continue to operate from the previously programmed information. Changing parameters and information on switchboard controls are covered in detail in Section 8 of this manual.

Section 5

Safety Considerations

Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F)

Maximum relative humidity of less then 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

Detector Connector

Caution:

The detector operating voltage (HV) is supplied to the detector by way of the input connector. A mild electric shock may occur if contact is made with the center pin of the input connector. Switch the Model 2241 to the OFF position before connecting or disconnecting the cable or detector.

Warning Markings and Symbols

Caution!

The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

The Model 2241 Survey Meter is marked with the following symbols:

CAUTION, RISK OF ELECTRIC SHOCK (per ISO 3864, No. B.3.6): designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.

CAUTION (per ISO 3864, No. B.3.1): designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

Warning!

The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:

1. Turn the instrument power OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing any internal components.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding. Each material must be separated. The symbol is placed on the battery compartment. See Section 9, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union.

Section 6

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2241 instrument may be externally cleaned with a damp cloth (using only water as the wetting agent). Do not immerse the instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.

2. Allow the instrument to sit for one minute before performing any external cleaning or accessing internal components for maintenance.

Recalibration

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered to be maintenance and do not normally require the instrument to be recalibrated.

Note:

Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate regulations to determine required recalibration intervals.

Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments, but most other manufacturers' instruments as well.

See Section 8, "Instrument Setup," for further details on instrument calibration.

Batteries

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very dusty or corrosive atmosphere, more frequent battery servicing should be used. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removing the handle will facilitate access to these contacts.

Note:

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure can occur at temperatures as low as 38 °C (100 °F).

Section
7

Technical Theory of Operation

Refer to the Main Board schematic for the following:

Detector Input/Amplifier

Negative-going detector pulses are coupled from the detector through C021 to Amplifier U021. R024 and CR021 protect the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R022, divided by R025. Transistor pins 4, 5, and 6 of U021, provide amplification. Pins 10-15 of U021 are coupled as a constant current source to pin 6 of U021. The output is self-bias to 2 Vbe (approximately 1.4 volts) at pin 7 of U021. This provides just enough bias current through pin 6 of U021 to conduct all of the current from the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminator (U011) through R031 and C012.

Discriminator

Positive pulses from amplifier U021 are coupled to pin 2 of U011 comparator. The discrimination level is set by the DISC control connected to pin 3 of U011. As the positive pulses at pin 2 of U011 increase above DISC reference at pin 3, pin 1 goes low, producing a low pulse. Pin 1 of U011 is normally held high (+5 volts) by R014.

The low pulse from pin 1 of U021 is coupled to univibrator U001. U001 shapes and fixes the pulse width to approximately 10 µs. The Univibrator is configured in the non-retriggerable mode. Negative pulses from pin 9 of U001 are coupled to the µP for counting.

Low-Voltage Supply

Battery voltage is coupled to DC-DC converter U231. U231 and related components provide +5V to power the µP, op-amps, and logic circuitry. R135 and R136 provide voltage division for low-battery detection. Pin 6 of U231 provides a low signal when the battery voltage decreases to +2.2 ±0.1 Vdc. U121 provides the +2.5 Vdc reference for the HV and DISC control references.

High-Voltage Supply

High voltage is developed by blocking oscillator Q241, T141, and C244 and rectified by voltage multiplier CR041-CR043, C041-C043, and C141. High voltage increases as current through R241 increases, with maximum output voltage with Q241 saturated. High voltage is coupled back through R034 to op-amp pin 2 of U131. Resistor network R027, R132 completes the HV division circuit to ground. R027 provides HV limit from 1250-2400 when the HV control on the calibration board is at maximum. The regulated HV output is controlled by the HV1 and HV2 potentiometers located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U131. During stable operation, the voltage at pin 2 of U131 will equal the voltage at pin 3 of U131. Pin 1 of U131 will cause conduction of Q141 to increase or decrease until the HV finds a level of stability.

Detector Overload

A voltage drop is developed across R031 and sensed by comparator pins 5, 6, and 7 of U131 as detector current increases. When the voltage at pin 5 of U012 goes below pin 6, pin 7 goes low, signaling U111 (µP) to send the OVERLOAD alarm to the LCD. OVL (underneath CAL cover) control provides adjustment for the overload set point.

Microprocessor (µP)

U111 controls all of the data, control inputs, and display information. The clock frequency is crystal-controlled by Y221 and related components at 6.144 MHz. The µP incorporates internal memory (ROM), storing the program information. U1 resets the µP at power-up to initiate the start of the program routine. During the program loop, the µP looks at all the input switches for initiation or status changes and responds accordingly. U122 is a 256 x 8 bit EEPROM used to store the setup parameters. The information is transferred serially from the µP. The EEPROM is non-volatile and retains memory even after power is removed.

Audio

Click-per-event, divide-by, and alarm audio pulse frequency is generated by the µP and coupled to Q101. Q101 then inverts the pulses and drives the bottom of T101. Bias voltage is provided by the volume control (R002) to the top of T101.

Refer to the Switch Board schematic for the following:

S1 (FUNCTION)

S1 is a 16-position binary rotary switch, which selects the programmable parameters for the Model 2241. The switch selects the parameters using the hexadecimal numbering system via buss lines SW1-SW4.

S2-S4

S2-S4 are pushbutton switches that enter/change the variables for each of the 16 parameters.

U1

U1 is a +5V powered RS-232 driver/receiver used to interface the Model 2241 to a computer.

Refer to Display Board schematic for the following:

LCD Drive

U1 and U2 are serial input 32-bit LCD drivers. The data is loaded serially into the 32-bit shift registers (internal) via the "D" IN input. The LOAD input instructs the shift register to receive data while the CLOCK input shifts the data through the 32-bit registers. After all the data is loaded, the LOAD line is pulsed by the µP, instructing the registers to transfer the data to the LCD drivers. The backplane (BP) signal from U2 provides the reference signal (approximately 125 Hz at 5 Vdc) to the LCD (DSP1) BP connection. When a segment is illuminated, the signal to that segment will be out-of-phase with the BP signal. If the segment is OFF, the signal will be in-phase with the BP signal.

Backlight Drive

Depressing the LIGHT button instructs the µP to set the BACKLIGHT line, pin 31 on µP, "low" for the predetermined backlight ON time. (Refer to main board schematic for details.) A "low" condition on pin 31 causes Q212 to conduct, sending +3V to P8-3 on display board (refer to display board schematic). Backlight oscillator Q011, T011 and related components start to oscillate, producing a 2.5 kHz sine wave signal. The signal is amplified by T011 to 150 volts peak-to-peak to drive the LCD backlight.

Section 8

Instrument Setup

Entering or Changing Switch Board Parameters

On the switch board, select the desired parameter to enter or change by using the corresponding FUNCTION switch position. Depress the ENTER button and a character on the LCD will start to flash. The flashing character indicates that the program is in the parameter change mode.

To change the character, press the UP button until the desired variable is reached. To shift to another character, increment the LEFT pushbutton until the desired character is reached. The LEFT pushbutton enables the operator to sequence through all the characters on the LCD associated with a particular parameter.

Once the desired data is entered, depress the ENTER button. The LCD characters should stop flashing and the new parameter data should display.

To read pre-programmed setup parameters, switch the FUNCTION switch to position A and select the pre-programmed detector setup number, using the parameter change procedure above. Once the detector setup number is entered, sequence through the parameters by varying the function switch to read the variables for that specific detector number.

Note:

Once the detector setup number has been entered, the function switch can be rotated either direction to view the parameter variables.

THE FUNCTION SWITCH

- **FUNCTION Switch**: a 16-position rotary switch labeled "0-9" and "A-F." This switch selects a parameter setup mode for the Model 2241. If the board is not installed, the normal operation mode (counting mode) is selected. If the switch board is installed, the selector switch must be set to the 0 position for normal instrument operation. The following may be changed using the switch board, and are discussed in detail in this section:

- Detector Parameters
- Current Detector Setup in Use
- RS-232 Communication Baud Rate
- RS-232 Data Dump Mode
- RS-232 Detector Parameters Set/Read Mode

FUNCTION SWITCH POSITION DESCRIPTIONS AND VARIABLES

POSITION 0: NORMAL OPERATION places the Model 2241 in the normal (counting) operating mode. Unplugging the switch board from the Model 2241 main board defaults to the normal operating mode.

POSITION 1: DEAD TIME (µs) allows changing the detector dead time correction for the current detector setup. Setting this parameter to 0 disables dead time correction. The dead time adjusts from 0 to 9999 microseconds (µs). The incoming counts are adjusted for dead time using the following formula: where,

$$n = \frac{m}{1 - m\tau}$$

n = corrected counts per second
m = incoming count per second
τ = system dead time

POSITION 2: CALIBRATION CONSTANT allows changing the calibration constant for the current detector setup. The calibration constant (CC) adjusts from 0.001 to 280 X 10^9. The calibration constant converts counts/time base to units/time base. The CC must be set to 1 to readout in cps (counts per second) or cpm (counts per minute).

$$CC = \frac{cps\ x\ time\ base}{rate}$$

CC CONVERSION TABLE

Conversion Rate	Multiply	by to get CC
cps/µR/hr		3.6 x^{9}10
cps/mR/hr	3	.6 x 10^6
cps/R/hr		3.6 x^{3}10
cpm/µR/hr		6.0 x^{7}10
cpm/mR/hr	6	.0 x 10^4
cpm/R/hr		6.0 x^{1}10
cps/µSv/h	3	.6 x 10^7
cps/mSv/h		3.6 x^{4}10
cps/Sv/h	3	.6 x 10^1
cpm/µSv/h	6	.0 x 10^5
cpm/mSv/h		6.0 x^{2}10
cpm/Sv/h	0	.6

Example:

The Model 44-9 GM detector produces approximately 3300 cpm/mR/hr for ^{137}Cs: □ 6.0 x 10^4 x 3300 = 198 x 10^6 for CC.

POSITION 3: DISPLAY UNITS selects the display units for the associated detector setup number. The Model 2241 and detector may be calibrated in either exposure rate (R/hr or Sv/h) by entering the appropriate Calibration Constant (position 2) and Dead Time correction (position 1). The Model 2241 will automatically convert to the correct reading when switching between R and Sv.

The time base for count "C" is set independently in position 4. The display units may be set to:

R/hr (Roentgens per hour)
Sv/h (Sieverts per hour)
C/time base (Counts per time)

The display is auto-ranging with the appropriate multiplier symbol appearing in front of the "R," "Sv," or "C," indicating the range:

µR/hr, mR/hr, R/hr
µSv/h, mSv/h, Sv/h
C/s, kC/s, C/m, kC/m

POSITION 4: TIME BASE is set to CPS or CPM, which selects the display time base for the current detector setup. This time base only applies if the units are set to C/ (Counts/time). The time base for R/hr and Sv/h is fixed in "hr." For "true" reading (Pulser calibration) cpm or cps calibrations, set the Calibration Constant (CC, parameter 2) to read "1." For geometry calibrations, the detector efficiency can be entered for CC.

Example:

For alpha scintillation detector with 25% 2π efficiency, enter 250 x 10^{-3} in the CC parameter setup.

The display time base may be set to:

seconds (**s**)
minutes (m)

POSITION 5: AUDIO DIVIDE BY selects the audible clicks-per-event division rate for the current detector setup. If the AUD ON OFF switch is in the OFF position, no audible clicks per event will be heard.

This parameter ranges from:

0 Divide-By 1
1 Divide-By 10
2 Divide-By 100
3 Divide-By 1000

POSITION 6: RESPONSE TIME allows changing the time constant (TC) for the current detector setup. If the response is set to 0, the Model 2241 automatically calculates (for variable mode) the time constant based on the incoming cps. If a variable of 1-199 is entered for TC, the response time becomes fixed.

Variable Response: Response time is varied in proportion to the incoming count rate. The two-position F/S (Fast/Slow) toggle switch selects the maximum time constant (TC) for the variable mode. The fast position varies the TC from 4-25 seconds, and the slow position varies from 4-60 seconds.

Fixed Response: The Fast (F) response position is programmable from 2-50 seconds, and the slow response is five times slower than the fast TC. For MDA-type measurements, the fixed response time mode is recommended.

POSITION 7: RATEMETER ALARM/ALERT allows changing the ratemeter alarm for the current detector setup. The units of this alarm are the same as the units for the ratemeter display. The fifth push of the left button allows the decimal point to be moved. The ratemeter alarm adjusts from 1 to 999 R/hr (or Sv/h), 1 to 999 kcpm, or 1 to 999 kcps. The units of the alarm are determined by the units for the ratemeter.

POSITION 8: SCALER ALARM/COUNT TIME sets the scaler alarm variable from 1-999999, corresponding to the accumulated scaler count. After the scaler alarm variable is entered, the scaler count time is prompted. The scaler count time is adjustable from 1-9999 seconds.

POSITION 9: NOT USED

POSITION A: DETECTOR SETUP NUMBER allows the current detector setup to be changed to one of the six different detector setups. The detector setups are stored in EEPROM. Enter the detector setup number first before entering or changing the related detector parameters.

POSITION B: LCD Backlight ON TIME is the amount of time that the LCD backlight will stay on after pressing the front-panel switch labeled LIGHT. This value is stored in EEPROM.

Available values are:

5 seconds
30 seconds
60, 90 seconds
180, 240 seconds.

POSITION C: SET MINIMUM DISPLAY sets the ratemeter minimum displayable reading. Depressing the RESET button displays the minimum ratemeter units. The readout will auto-range up to the maximum displayable but will display 0 for ratemeter readings below the user-programmed minimum variable.

Minimum displayable values are:

00.0 µ, 000 µ, 0.00 m, 00.0 m, 000 m, 0.00, 00.0, 000 R/hr

.000 µ, 000 µ, 00.0 m, 000 m, 0.00, 00.0, 000 Sv/h

0.00, 00.0, 000, 0.00 k, 00.0 k, 000 kcpm or cps

POSITION D: RS-232 DATA DUMP MODE allows the RS-232 port to dump ratemeter data every two seconds. The Model 2241 is fully functional during RS-232 data dump with the exception of the audio function. The LCD will alternate between display of the ratemeter and the word "**dUP**" (representing "dump").

POSITION E: RS-232 DETECTOR PARAMETERS SETUP MODE allows the RS-232 port to accept/send a string of parameters corresponding to the current detector setup values.

POSITION F: BAUD RATE configures the RS-232 port for the following baud: 150, 300, 600, 1200, 2400, 4800, 9600, and 19200. The data is 8 data bits, 1 stop bit with no parity bit. This value is stored in EEPROM. The baud rate can only be programmed through the switch board.

RS-232 PORT CONNECTOR: This 9-pin "D" type connector is designed as a DCE port. A straight wire cable (extension cable) connects the Model 2241 to a computer's 9-pin RS-232 port.

RS-232 CONNECTOR PIN OUT:

PIN	FUNCTION
1	NC (No Connection)
2	DATA OUT
3	DATA IN
4	NC
5	NC
6	NC
7	HANDSHAKING IN
8	HANDSHAKING OUT
9	NC

Note:

Ludlum Measurements, Inc. offers a PC compatible software program, which incorporates the read/write commands necessary to communicate between the PC and the Model 2241. The program also incorporates an algorithm to calculate the detector Calibration Constant and Dead Time Constant. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024).
Read the Software License Agreement at the end of this section prior to installing any LMI software. If you cannot comply with the agreement, DO NOT install the software.

Loading Default Parameters

To load the default parameters for all detector setups, hold down the UP pushbutton on the switch board, while turning the instrument on, until DEF is displayed on the LCD. The following table shows the default values.

Model 2241	cpm	cpm	cpm	cpm	cpm	cpm
	Setup 01	Setup 02	Setup 03	Setup 04	Setup 05	Setup 06
Dead Time	0 s	0 µs	0 µs	0 µs	0 µs	0 µs
Cal Const	100e-2	100e-2	100e-2	100e-2	100e-2	100e-2
Rate Alarm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm	50.0 kcpm
Scaler Alarm	85000	85000	85000	85000	85000	85000
Count Time	12 Secs	12 Secs	12 Secs	12 Secs	12 Secs	12 Secs
Time Base	Mins	Mins	Mins	Mins	Mins	Mins
Units	cpm	cpm	cpm	cpm	cpm	cpm
Audio Divide-By	1	1	1	1	1	1
Response	0	0	0	0	0	0
Check Source	0	0	0	0	0	0
Percent CS	0	0	0	0	0	0
Rate Alert	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm	20.0 kcpm
Min Display	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm	0.00 cpm
Baud Rate	9600					
LCD Time Off 5	seconds					
Detector	0					

Calibration

The Model 2241 calibration routine consists of entering detector parameters into memory by way of the switch board and adjusting the CAL controls (HV, DISC, and OVL) for the specific detector operating requirements.

The first subsection of calibration will give a general overview of detector setup, including the determination of various detector operating voltages (HV) and the adjustment of counter input sensitivity (DISC).

The next subsection deals with pulse generator counts-per-minute calibration. The counts-per-minute parameter setup is used in the initial instrument checkout procedure, and the variables are saved under detector setup number "1" when shipped from Ludlum Measurements, Inc.

The following subsection deals with exposure-rate calibration. The detector Calibration Constant (CC) and Dead Time Correction (DTC) are the two primary parameters used in the exposure-rate calibrations (R/hr and Sv/h). These two constants are alternately varied to achieve linearity at the detector non-linear operating regions. An example of the Ludlum Model 44-9 GM detector calibration is given at the end of this section to illustrate the algorithm used in determining the CC and DTC variables.

The last subsection of calibration deals with the Detector Overload (OVL).

GENERAL DETECTOR SETUP INFORMATION

The operating point for the instrument and probes is established by setting the probe voltage and instrument sensitivity (HV and DISC). The proper selection of this point is the key to instrument performance. Efficiency, background sensitivity, and noise are fixed by the physical makeup of the given detector and rarely vary from unit to unit. However, the selection of the operating point makes a marked difference in the apparent contribution of these three sources of count.

In setting the operating point, the final result of the adjustment is to establish the system gain so that the desirable signal pulses (including background radiation) are above the discrimination level and the unwanted pulses from noise are below the discrimination level and are, therefore, not counted.

The total system gain can be controlled by adjusting either the instrument sensitivity or the high voltage. HV controls the gain of the detector; and DISC (Discriminator) controls the instrument counting threshold (sensitivity).

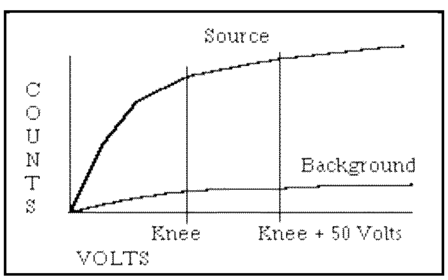
In the special case of GM detectors, a minimum voltage must be applied to establish the Geiger-Mueller characteristic. Further changes in HV will have little effect on this type of detector.

GM Detectors: The output pulse height of the GM detector is not proportional to the energy of the detected radiation. Adjusting DISC will have minimal effect on observed count rate unless the DISC setting is so low that the instrument will double pulse.

For most GM detectors, set DISC for 30-40 millivolts and adjust HV to the GM detector recommended high voltage. Most GM detectors operate at 900 volts, although some miniature detectors operate at 450-550 volts. If a recommended setting is unavailable, plot count rate versus HV to produce a plateau graph. Adjust the HV for 25-50 volts above the knee or start of the plateau. For mixed detector use, both sensitivity and high voltage may be "tailored" for other detectors as long as the GM detector is operated within the recommended voltage range. Caution must be observed in lowering the input sensitivity to ensure that the counter does not double or multi pulse.

Alpha Air-Proportional Detectors: For air proportional alpha detectors, set the DISC for 2-millivolt discrimination. Adjust HV until the detector just breaks down (shown by a rapid increase of count rate without a source present). Measure the HV output; then decrease the HV setting to operate 100 volts below breakdown.

Proportional Detectors: For proportional detectors, set the DISC control for 2-millivolt discrimination (near maximum clockwise). Expose the detector to a check source and plot count rate versus HV, similar to the one in the figure below. Refine the HV adjustment for optimum source efficiency with a minimum acceptable background count.



Scintillators: Set the DISC for 10 millivolts. Plot background and source counts versus HV to produce a plateau graph similar to the one in the figure. Adjust the HV to 25-50 volts above the knee or start of the plateau. This provides the most stable operating point for the detector.

COUNTS PER MINUTE (C/M) CALIBRATION

This procedure will setup the Model 2241 for the counts per minute (C/m) mode of operation. Refer to Section 8, (Page 8-2 and following) for more information on setting up parameter variables.

A Ludlum Model 500 Pulser or equivalent is required. If the pulser does not have a high-voltage display, use a high-impedance voltmeter with at least 1000 megohms input resistance to measure the detector high voltage.

Switch SCALER/RATEMETER to the RATEMETER position.

Select FUNCTION switch positions "1-6" and adjust for the following parameters:

Switch Pos.	Parameter	Function
1 0	000 s_{6}	Dead Time
2	0100 -2	Calibration Constant
3 c	/ D	isplay Units
4 m	T	imebase
5 1	A	udio Divide-by
6	000 s	Response Time

Position 7 selects the desired ratemeter ALERT and ALARM trip points.

If the parameters are undetermined, arbitrarily choose "0050 kC/m" for the alarm and "0045 kC/m" for the alert to confirm operation of the alert/alarm function.

Position 8 selects the scaler ALARM parameter and the scaler count time.

If the values are unknown, set the scaler alarm to "$4500_{ALARM00}$" and the count time to "0060" (60 second count time).

Position 9 is not used, and position A is not used.

Switch to position B and enter "15" for a 15-second backlight "ON" time.

Switch to position C and enter "00.0 C/m" for the minimum displayable value.

Select position 0 to return to normal operation.

Connect the Model 500 Pulser to detector input and adjust HV and DISC to the specific detector operating parameters.

- Adjust the pulser amplitude to 1.5 times the Model 2241 discrimination level.
- Adjust the pulser output to 800 cpm and confirm that the Model 2241 reads 800 C/m ± 10% on the ratemeter setting.
- Adjust the pulser output to 200 cpm and confirm that the Model 2241 reads 200 C/m ± 10% on the ratemeter setting.
- Adjust the pulser output to 800 cpm, take a one-minute count, and confirm that the digital scaler readout displays 800 C/m ± 2%.
- Adjust the pulser output to 200 cpm, take a one-minute count, and confirm that the digital scaler readout displays 200 C/m ± 2%.
- Confirm that the 20% and 80% readings for the upper decades are within the pulser input by decading the pulser count output.
- Confirm that the scaler readout is within 2% of the pulser input rate.
- Ensure that the ALERT and ALARMs function by inputting the preset alarm levels as to initiate the alert and alarm conditions.

R/hr CALIBRATION

The following calibration procedure assumes that detector Calibration Constant (CC) and Dead Time Constant (DTC) are already known. If these constants must be determined, reference the following subsection, "Determining CC and DTC."

Switch the toggle switch to DET2. Detector setup number 1 is usually reserved for the counts per minute parameter calibration. Rotate the FUNCTION switch counterclockwise to position 1 and enter the detector Dead Time in µs. Rotate to position 2 and enter the Calibration Constant. Enter the desired parameters for positions 3-F. Switch to position 0 for normal operation.

Expose the detector to calibrated radiation fields extending from the lower to the upper operating range of the detector. Confirm that the linearity is within 10% of each respective reading. If the readings are off on the lower detector operating region, vary CC. If the readings are off at the upper end of the detector operating region, adjust DTC.

DETERMINING CC AND DTC

This procedure contains the algorithm (*hi-lo method*) for determining the CC (Calibration Constant) and the DTC (Dead Time Correction). An example of the Ludlum Model 44-9 GM detector calibration is used in conjunction with the algorithm calculations to aid in solving the equations.

Note:

Ludlum Measurements, Inc. offers a PC-compatible software program, which incorporates the read/write commands necessary to communicate between a PC and the Model 2241. The program also incorporates the algorithm to calculate the detector CC and DTC. The software is offered in a DOS version (part number 1370-025) or a WINDOWS version (part number 1370-024).

Hi-Lo Method: The hi-lo method refers to the placement of the detector in a radiation field using a two-point (CC and DT) calibration to make the detector response linear, even in the non-linear operating regions of the detector. The low-radiation field (CC) should be a field that yields from 2 to 5% count loss. The high radiation field (DT) should be a field that yields from 30 to 60 percent count loss. The algorithm ignores background counts, and therefore, the low field must be at least 10 times the background count.

The following summary lists the calibration constraints.

Calibration and Dead Time Calibration Constraints

FIELD	CONSTRAINT
BACKGROUND	*10 times less than low field
LOW FIELD	Yields from 2 to 5 percent count loss
HIGH FIELD	Yields from 30 to 60 percent count loss

* This constraint only applies when using two sources (two fields) or a radiation range calibrated without background consideration.

Preliminary CPS Setup

Refer to Section 8, subsection, "Function Switch Position Descriptions and Variables," for cps readout variables.

Starting with FUNCTION switch position 1, enter the following variables:

SWITCH POS.	PARAMETER	FUNCTION
1	0 000s$_{-6}$	Dead Time
2	0100 -2	Calibration Constant
3	C /	Display Units
4	m	Timebase
5	N/A	Audio Divide-By
6	N/A	Response Time
7	N/A	Ratemeter Alm./Alert
8	0060 s	Scaler Alm./Count Time
9	Not Used	
A	Not Used	
B	N/A	LCD Backlight
C	000 C/s	Set Minimum Display
D-F	N/A	RS-232 Parameters

Equation 1

$$CPS^{LO_{2\%}} = \frac{1}{49 DT}$$

Equation 2

$$CPS^{LO_{5\%}} = \frac{1}{19 DT}$$

Equation 3

$$CPS^{HI_{30\%}} = \frac{1}{2.3333 \ x \ DT}$$

Equation 4

$$CPS^{HI_{60\%}} = \frac{1.5}{DT}$$

The equations to the left (Equations 1-4) determine the *hi* and *lo* radiation fields used to acquire counts for the CC and DTC algorithm. These calculations require an unknown variable, DT (Dead Time). Typical dead times for some of the standard LMI detectors are referenced in the table at the end of this section. The *lo* count field should be a field that yields between 2 and 5% count loss. The *hi* count field (CPS^{HI}) should be a field that yields between 30 and 60% count loss.

Reference the table at the end of this section to determine the cps/exposure rate (cps/ER). The conversion can be determined by placing the detector in a radiation field that produces from 50 to 200 cps. Calculate the count/exposure rate using the equation to the left.

$$\frac{cps}{radiation\ field\ in\ exposure\ rate\ units} = cps / ER$$

For example, exposing a LMI Model 44-9 to a 2 mR/hr ^{137}Cs field yields approximately 110 cps so that:

$$\frac{110\ cps}{2\ mR/hr} = 55\ cps/mR/hr$$

The typical dead time for a Model 44-9 is approximately 85 µs. Therefore, using 85 µs for "DT" in equations 1-4, the *lo* field should be between 240 and 619 cps, and the *hi* field is between 5040 and 17,650 cps. Dividing the cps values by the 55 cps/mR/hr conversion equates to between 4 and 11 mR/hr for the *lo* field and 91 and 320 mR/hr for the *hi* field.

Select a calibrated field between the *lo* and *hi* data points determined above:

lo (CAL_{lo}) = 8 mR/hr

hi (CAL_{hi}) = 200 mR/hr

The following procedure outlines the hi-lo method

Abbreviations used:

units = Sv, R, counts.

CAL_{lo} = *lo* field calibration point.
CAL_{hi} = *hi* field calibration point.

$CORR_{lo}$ = recorded field at low calibration point.
$CORR_{hi}$ = recorded field at high calibration point.

DT = dead time constant entered into Model 2241.
CC = calibration constant entered into Model 2241.

f_d and a_d are intermediate steps in calculating DT.
f_{cal} is an intermediate step in calculating CC.

CC and DTC Algorithm

Equations (5) and (6) convert units per time (R/hr Display Units) to units per second:

$$\frac{UNITS}{time} \rightarrow \frac{UNITS}{second}$$

Insert the cps *lo* data point (8 mR/hr for the Model 44-9 example) determined from equations (1) and (2):

Equation 5

$$CAL_{lo} = (0.008\frac{R}{h}) \times (\frac{1\,h}{60\,m}) \times (\frac{1\,m}{60\,s}) = 2.22 \times 10^{-6}\ s$$

Insert the cps hi data point (200 mR/hr for the Model 44-9 example) determined from equations (3) and (4):

Equation 6

$$CAL_{hi} = (0.200\frac{R}{h}) \times (\frac{1\,h}{60\,m}) \times (\frac{1\,m}{60\,s}) = 55.6 \times 10^{-6}\ s$$

Place the detector in the low field and enter the counts per second:

Equation 7

$$CORR_{lo} = \frac{SAMPL_{lo}}{count\ time} = \frac{counts}{s}$$

Note:

The low-field count sample should be ≥ 3000 counts. Use the Scaler and adjust the count time to accumulate count ≥ 3000.

As an example, assume a 60-second count sample in a low field of 8 mR/hr:

Example

$$CORR_{lo} = \frac{26,427}{60} = 440 \ C/s$$

Place detector in the high field and enter the counts per second:

Equation 8

$$CORR_{hi} = \frac{SAMPL_{hi}}{count \ \ time} = \frac{counts}{s}$$

Counts/second sample in high field of 200 mR/hr:

Example

$$CORR_{hi} = \frac{5830}{1} = 5830 \ C/s$$

Insert the values calculated in equations (5), (6), (7), and (8) and solve for f_d:

Equation 9

$$f_d = CAL_{hi} - \frac{CORR_{hi} \times CAL_{lo}}{CORR_{lo}} = \frac{units}{s}$$

Example

$$f_d = 55.6 \times 10^{-6} - \frac{5830 \times 2.22 \times 10^{-6}}{440} = 26.2 \times 10^{-6} \ s$$

Solve for a_d:

Equation 10

$$a_d = (CAL_{hi} \times CORR_{hi}) - (CAL_{lo} \times CORR_{hi}) = \frac{units \cdot count}{s^2}$$

Example

$$a_d = (55.6 \times 10^{-6} \times 5830) - (2.22 \times 10^{-6} \times 5830) = 31.1 \times 10^{-6}$$

Enter the results of equations (9) and (10) into equation (11) to solve for DT:

Equation 11

$$DT = \frac{f_d}{a_d} = \frac{s}{count}$$

Example

$$DT = \frac{26 \quad 2x10^{-6}}{31 \quad 1x10^{-2}} = 4.8x10^{-6}\ s$$

Solve for f_{cal}:

Equation 12

$$f_{cal} = CAL_{lo} - (CAL_{lo} \times CORR_{lo} \times DT) = \frac{units}{s}$$

Example

$$f_{cal} = 2.22 \times 10^{-6} - (2.22 \times 10^{-6} \times 440 \times 4.8 \times 10^{-6}) = 2.14 \times 10^{-6}\ s$$

Enter the result of equation (12) into:

Equation 13

$$CC = \frac{CORR_{lo}}{f_{cal}} = \frac{count}{units}$$

and solve for CC:

Example

$$CC = \frac{440}{2.14 \times 10^{-6}} = 206 \times 10^{6}$$

Enter the CC and DT values (positions 1 and 2 of the FUNCTION switch), derived from the equations above. Perform an "R/hr calibration" as described in the previous subsection in order to ensure that the instrument and detector have been correctly calibrated.

Model 44-9 Detector Parameter Setup

FUNCTION			PARAMETER
1		0	084 s -6
2		0	206 06
4		N	/A
5	-8	a	s desired
B	-C	a	s desired
D	-F	i	f applicable

Typical Count Rate and Dead Time for LMI Detectors

D MODEL & TYPE		COUNT RATE		EAD TIME in µs (microseconds)
44-6, GM	2	0 cps/mR/hr	9	0-110 µs
44-9, GM	5	5 cps/mR/hr	8	0-90 µs
44-7, GM	3	5 cps/mR/hr	2	40-290 µs
133-2, GM	1	7.5 cps/mR/hr	4	0-55 µs
133-4, GM	2	cps/mR/hr	4	0-55 µs
133-6, GM	0	.3 cps/mR/hr	4	0-55 µs
44-2, Gamma Scint.	2	800 cps/mR/hr	8	-12 µs*
44-10, Gamma Scint.	1	5,000 cps/mR/hr	1	8-20 µs
44-3, Low-Energy Gamma Scint.		N/A, operated in Counts/units mode		8-12 µs*
44-21, Beta/Gamma Scint.		N/A, operated in Counts/units mode		8-12 µs*
43-5, Alpha Scint.		N/A, operated in Counts/units mode		20-28 µs

Note:

The data represented in the table above is typical. Actual values may vary among detector and instrument combinations. This table represents some of the common detectors operated with the Model 2241. Consult the LMI sales department for information concerning detectors not listed in the table above.

*The dead time values for these scintillation detectors are due to the dead time of the Model 2241 electronics.

DETECTOR OVERLOAD (OVL) CALIBRATION

Note:

The detector operating voltage (HV) must be determined and adjusted before the OVL adjustment is performed. If the HV is varied or another detector is substituted, OVL must be readjusted. If the overload feature is not used, adjust the control to the maximum counterclockwise position.

The detector overload circuit senses current flow through the detector. As the radiation intensity is increased, the detector may start to saturate (decrease pulse production), and the readout may decrease or read 0. But as the pulse output continues to decrease in the saturated field, the detector current drain continues to increase. This increase in current is detected by a comparator circuit, which triggers the OVERLOAD enunciator on the LCD by way of the microprocessor.

For GM and gamma scintillation detectors, the OVL trip point is adjusted to the point to where the readout no longer increases with increasing radiation intensity. In the event that the overload point cannot be determined due to radiation field limitations, adjust the overload point from 5 to 10 times the upper operating range of the detector.

Adjust the OVL control to the maximum counterclockwise position.

Place the detector in an increasing radiation field in which the readout no longer increases. Adjust the OVL control until the OVERLOAD alarm appears. Position the detector between the upper operating limit and the OVL set point and ensure the OVERLOAD alarm is defeated. Adjust the OVL control accordingly.

Example:

Ludlum Model 44-9 is calibrated with Model 2241 in the R/hr units display, utilizing DT. The upper linear operating point is 400 mR/hr for the Model 44-9. Place the detector at the 1000 mR/hr point and adjust the OVL control to initiate the OVERLOAD alarm. Place the detector in the 600-700 mR/hr field and ensure that the OVERLOAD is off.

The detector overload or saturation point for alpha and/or beta scintillation detectors is when the detector face (Mylar) has been punctured, allowing light to saturate the photomultiplier tube (PMT). The pulse output will decrease or even appear non-responsive to any radiation activity, depending upon the size of the puncture and the light intensity to the PMT.

Expose the detector PMT to a small light leak by loosening the detector window. Some scintillators incorporate a screw in the detector body, which when removed, will simulate a detector face puncture. The ratemeter readout should start to decrease as the light saturates the PMT.

Adjust the OVL control until the OVERLOAD just appears on the display. Reseal the light leak connection and expose the detector to a radiation source that will produce a near full-scale reading. Confirm that the OVERLOAD alarm does not initiate. Readjust the OVL control as required.

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Software License Agreement

Rev. (number) 1.0

Written by (or Revised by): Rich Oreola	**Date:** 20 Jan 06
Approved by: Ed Emm	**Date:** 20 JAN 06

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Section 9

Recycling

Ludlum Measurements, Inc. supports the recycling of the electronic products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronic products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding. Each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such: 

Section 10

Parts List

Model 2241 Survey Meter

Reference	Description	Part Number
UNIT	Completely Assembled Model 2241 Survey Meter	48-2444

Main Circuit Board, Drawing 408 × 223

Reference	Description	Part Number
BOARD	Completely Assembled Main Circuit Board	5408-223

CAPACITORS

Reference	Description	Part Number
C1	0.1µF, 50V	04-5663
C3	0.1µF, 50V	04-5663
C001-C002	47pF, 100V	04-5660
C011	0.001µF, 100V	04-5659
C012	0.1µF, 50V	04-5663
C021	100pF, 3KV	04-5532
C031	0.0047µF, 3KV	04-5547
C032	100pF, 3KV	04-5532
C033	0.0047µF, 3KV	04-5547
C041-C043	0.0047µF, 3KV	04-5547
C101	47µF, 10V	04-5666
C121	47µF, 10V	04-5666
C122-C123	27pF, 100V	04-5658
C131	0.0047µF, 3KV	04-5547
C132-C133	0.1µF, 50V	04-5663
C134	0.01µF, 50V	04-5664
C135	47µF, 10V	04-5666
C136	0.01µF, 50V	04-5664
C137	47µF, 10V	04-5666
C138	100pF, 100V	04-5661
C139	0.001µF, 100V	04-5659
C141	0.0047F, 3KV	04-5547
C241	1µF, 35V	04-5656
C242	68µF, 10V	04-5654
C243	0.1µF, 50V	04-5663
C251	68µF, 10V	04-5654

Category	Reference	Description	Part Number
TRANSISTORS	Q101	2N7002L	05-5840
	Q141	MMBT3904LT1	05-5841
	Q211	2N7002L	05-5840
	Q212	MMBT4403LT1	05-5842
	Q241	MJD210 RL	05-5843
INTEGRATED CIRCUITS	U1	MAX810LEUR	06-6424
	U001	CD74HC4538M	06-6297
	U011	TLC372ID	06-6290
	U021	CA3096M; 16=GND	06-6288
	U111	N87C51FC	06-6303
	U121	LM285MX-2.5	06-6291
	U122	X24C02S8T5	06-6299
	U131	LM358D	06-6312
	U231	LT1073CS8-5	05-5852
	*	SOCKET-44P	06-6613
DIODES	CR021	MMBD7000LT1	07-6355
	CR031	GI250-2	07-6266
	CR041-CR044	GI250-2	07-6266
	CR231	CXSH-4 EB33	07-6358
	CR241	MMBD914LT1	07-6353
	CR242	CXSH-4 EB33	07-6358
POTENTIOMETERS / TRIMMERS	R002	10K; 3269X1-103	09-6921
	R027	1M; 3269X1-105; HV LIMIT	09-6906
RESISTORS	R001	100K, 1/4W, 1%	12-7834
	R011-R012	10K, 1/4 W, 1%	12-7839
	R013	1K, 1/4W, 1%	12-7832
	R014	10K, 1/4W, 1%	12-7839
	R015	100K, 1/4W, 1%	12-7834
	R021	1M, 1/4W, 5%	10-7028
	R022	392K, 1/8W, 1%	12-7841
	R023	10K, 1/4W, 1%	12-7839
	R024-R025	4.75K, 1/4W, 1%	12-7858
	R026	8.25K, 1/8W, 1%	12-7838
	R031	4.7M, 1/4W, 5%	10-7030
	R032	1M, 1/4W, 5%	10-7028
	R033-R034	1G, FHV-1, 2%	12-7686
	R111-R113	22.1K, 1/4W, 1%	12-7843
	R121	100 Ohm, 1/4W, 1%	12-7840
	R122	6.81K, 1/4W, 1%	12-7857

	Reference	Description	Part Number
	R131	1M, 1/4W, 1%	12-7844
	R132	511K, 1/8W, 1%	12-7896
	R133	750K, 1/4W, 1%	12-7882
	R134	1M, 1/4W, 1%	12-7844
	R135	82.5K, 1/8W, 1%	12-7849
	R136	10K, 1/4W, 1%	12-7839
	R141	22.1K, 1/4W, 1%	12-7843
	R211	2.21K, 1/4W, 1%	12-7835
	R231	100Ohm, 1/4W, 1%	12-7840
	R241	2.21K, 1/4W, 1%	12-7835
	R242	200Ohm, 1/8W, 1%	12-7846
CRYSTALS	Y221	6.144 MHZ, 2=GND, 3=GND	01-5262
INDUCTOR	L231	100μH, CTX100-2	21-9740
TRANSFORMERS	T101	4275-083, AUDIO	4275-083
	T141	L8050	40-0902
MISCELLANEOUS	P1	1-640456-2, MTA100×12	13-8061
	P2	1-640456-3, MTA100×13	13-8100
	P3	640456-6, MTA100×6	13-8095
	P4	640456-2, MTA100×2	13-8073
	P5	1-640456-2, MTA100×12	13-8061
	*	CLVRLF	18-8771
Calibration Board, Drawing 408 × 12	BOARD	Completely Assembled Calibration Board	5408-007
POTENTIOMETERS	R1	100K, DISC	09-6813
	R2	1M, OVERLOAD	09-6814
	R3	1M, HV	09-6814
RESISTORS	R4	10K, 1/3W, 1%	12-7748
	R5-R6	1M, 1/3W, 1%	12-7751
	R7	1K, 1/3W, 1%	12-7750
CONNECTOR	P7	CONN-640456-6, MTA100×6	13-8095
Display Board, Drawing 408 × 259	BOARD	Completely Assembled Display Board	5408-259
CAPACITORS	C1	27PF, 100V	04-5658

	Reference	Description	Part Number
INTEGRATED CIRCUITS	U1	AY0438-I/L	06-6358
	U2	AY0438-I/L	06-6358
RESISTORS	R001-R004	10.0K, 1%, 125mW	12-7839
	R005	392 Ohm, 1%, 1/8 W	12-7054
MISCELLANEOUS	J1	CONN-640456-8, MTA100	13-8039
	DS1	EL-BACKLIGHT-LED	07-6527
	DSP1	MAIN DISPLAY; LCD-8246-365-4E1-A/W-REV1	07-6383
Switch Board, Drawing 408 × 45	BOARD	Completely Assembled Switch Board	5408-052
CAPACITORS	C1-C2	4.7µF, 10V	04-5578
	C3-C4	10µF, 20V	04-5592
	C5	4.7µF, 10V	04-5578
	C6	100µF, 10V	04-5576
INTEGRATED CIRCUITS	U1	MAX220EPE	06-6359
SWITCHES	S1	350134GSK; FUNCTION; 16 POS	08-6721
	S2	LEFT	08-6716
	S3	UP	08-6716
	S4	ENTER	08-6716
RESISTORS	R1-R2	22K	10-7070
MISCELLANEOUS	P6	CONN-1-640456-3, MTA100	13-8100
	P10	CONN-208006-2	13-8451
Chassis Wiring Diagram, Drawing 408 × 103			
AUDIO	DS1	UNIMORPH	21-9251
CONNECTORS	J1	CONN-1-640442-2, MTA100×2	13-8407

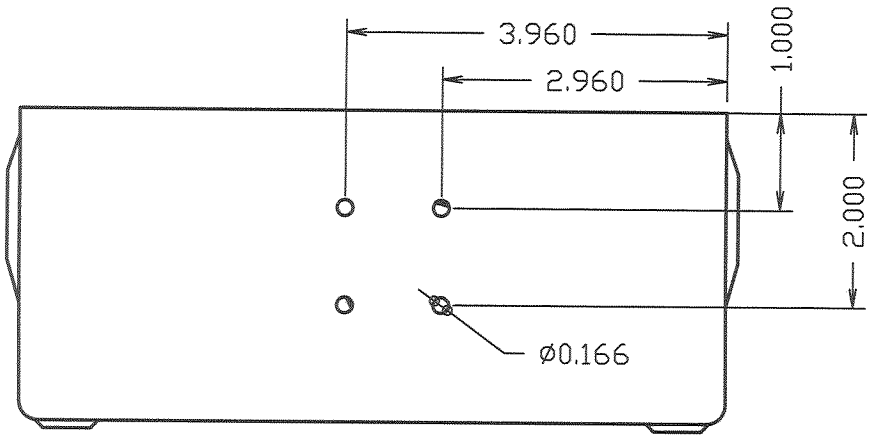
	Reference	Description	Part Number
	J2	CONN-1-640442-3, MTA100×3	13-8138
	J3	CONN-640442-6, MTA100×6	13-8171
	J4	CONN-640442-2, MTA100×2	13-8178
	J5	CONN-1-640442-2, MTA100×2	13-8407
	J6	CONN-1-640442-3, MTA100×3	13-8138
	J7	CONN-640442-6, MTA100×6	13-8171
	J8	CONN-640442-8, MTA100×8	13-8184
	J9	Series "C" -UG706/U	13-7751
	J10	JACK-09-9011-1-419	18-9080
	P10	HANDLE PIN	7408-055
SWITCHES	S1	30-1-PB GRAYHILL	08-6517
	S3-S4	7101-SYZ-QE C&K	08-6511
	S5	30-1-PB GRAYHILL	08-6517
	S6	PA-600-210	08-6501
	S7	MPS-103F	08-6699
	*	SWTCH CAP, BLK C-22	08-6698
BATTERIES	B1-B2	"D" Duracell Battery	21-9313
MISCELLANEOUS	*	DIGITAL BEZEL ASSY.	4408-020
	*	DIGITAL BEZEL W/GLASS	4408-051
	*	BEZEL BACK	7408-025
	*	BEZEL BACK GASKET	7408-026
	*	BATTERY CONTACT SET	40-1707
	*	MAIN HARNESS	8408-048
	*	MODEL 2241 CASTING	7408-043
	*	Portable HARNESS CAN WIRES	8363-462
	*	CAN ASSY.	4363-441
	*	PORTABLE KNOB	08-6613
	*	BATTERY LID WITH CNTCT	2363-191
	*	PORTABLE LATCH KIT WITHOUT BATTERY LID	4363-349

Reference	Description	Part Number
*	PORT CALIBRATION COVER WITH SCREWS	9363-200
*	MODEL 2241-2 RLLD HNDLE ASSY.	4408-178

Section 11

Drawings

REV #	ALTERATIONS	DATE	BY
2	VALID EC-381	4-25-97	JGW
3	VALID EC-1017	10-20-98	TJR

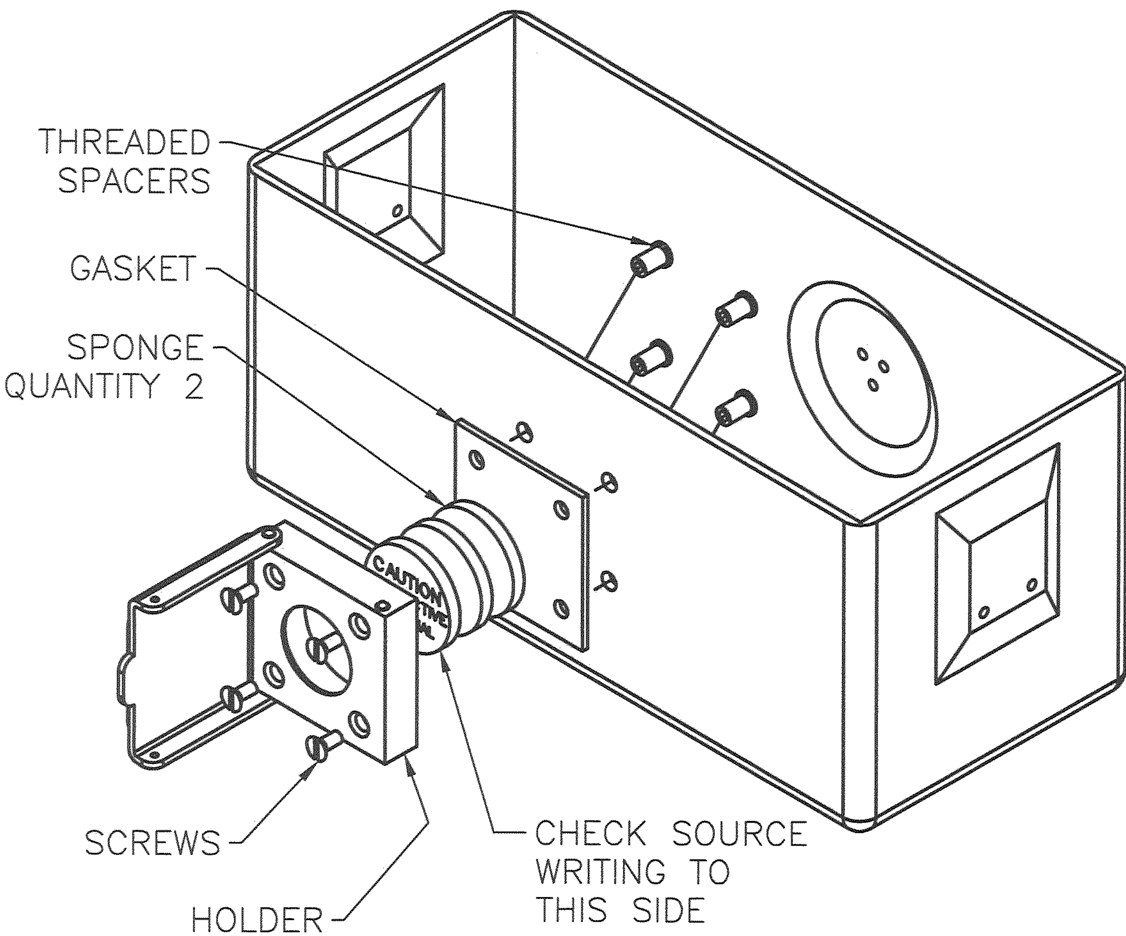


MOUNTING CHECK SOURCE

Normally, the check source holder is mounted on the side of the can opposite of the speaker. Use the drawing to the left to drill the holes in the can, or the holder can be used as a template to locate the holes. Insert the spacers into the holes with the flange inside the can and the spacer protruding to the outside of the can. Assemble the parts as shown in the lower left drawing. The printed side of the check source is the active side and should be facing out.

For check source readings, open the cover, place detector against the source, and note reading. It may be necessary to change to a higher range multiplier for an accurate reading.

To conform to 10 CFR 35.51, the licensee shall check each survey instrument for proper operation with the dedicated check source each day of use.

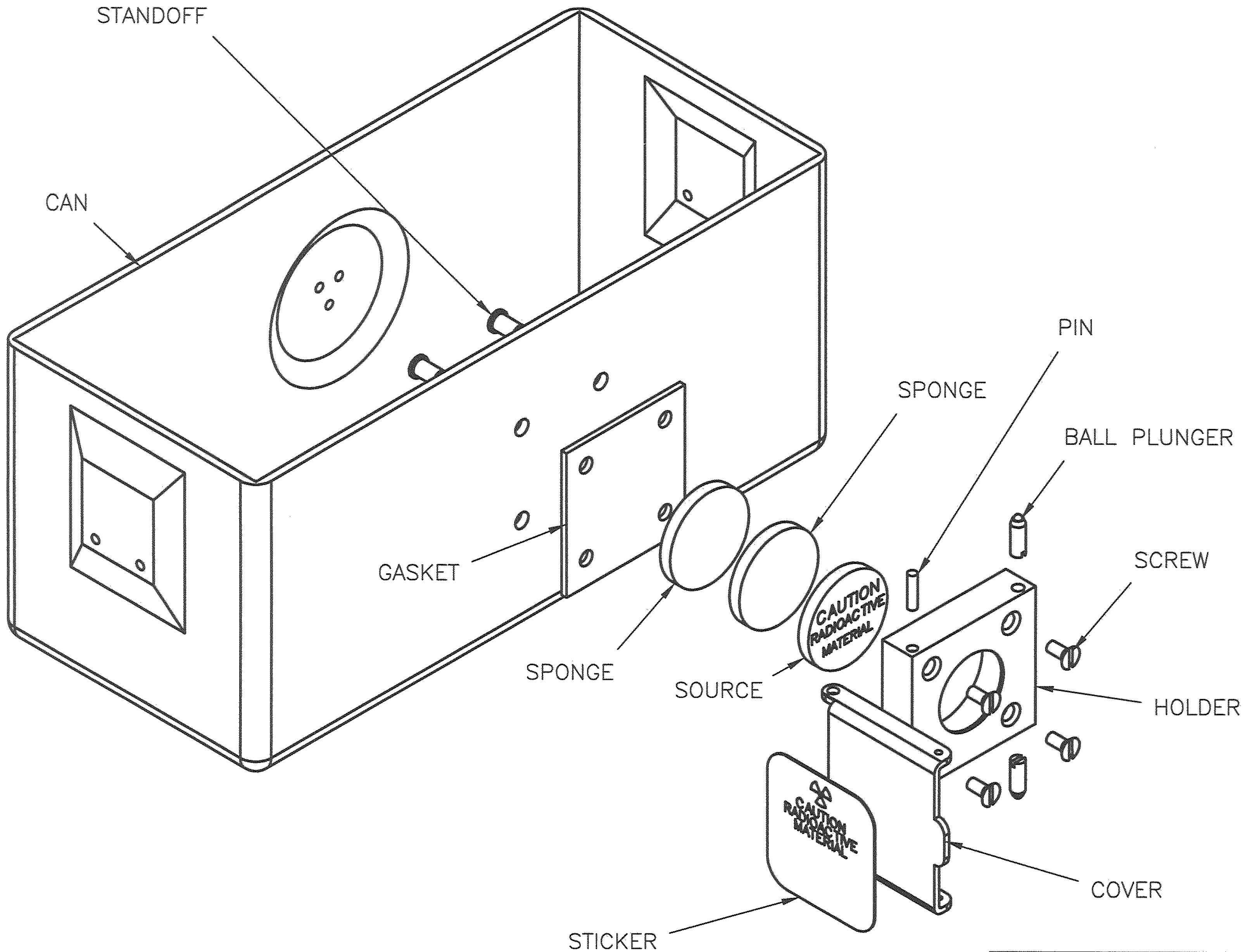


DWN	DATE	CHECKED	APPROVED
JGW	10-5-01	RSS 10-5-01	WLh 10-5-01

TITLE: SOURCE HOLDER ASSEMBLY

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556	SERIES 62	SHEET 166

REV #	ALTERATIONS	DATE	BY
2	VALID EC-381	4-25-97	JGW
3	VALID EC-1017	10-20-98	TJR

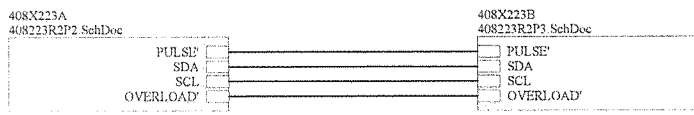


DWN	DATE	CHECKED	APPROVED
JGV	10-5-01	PW. 10-5-01	[illegible] 10-5-01

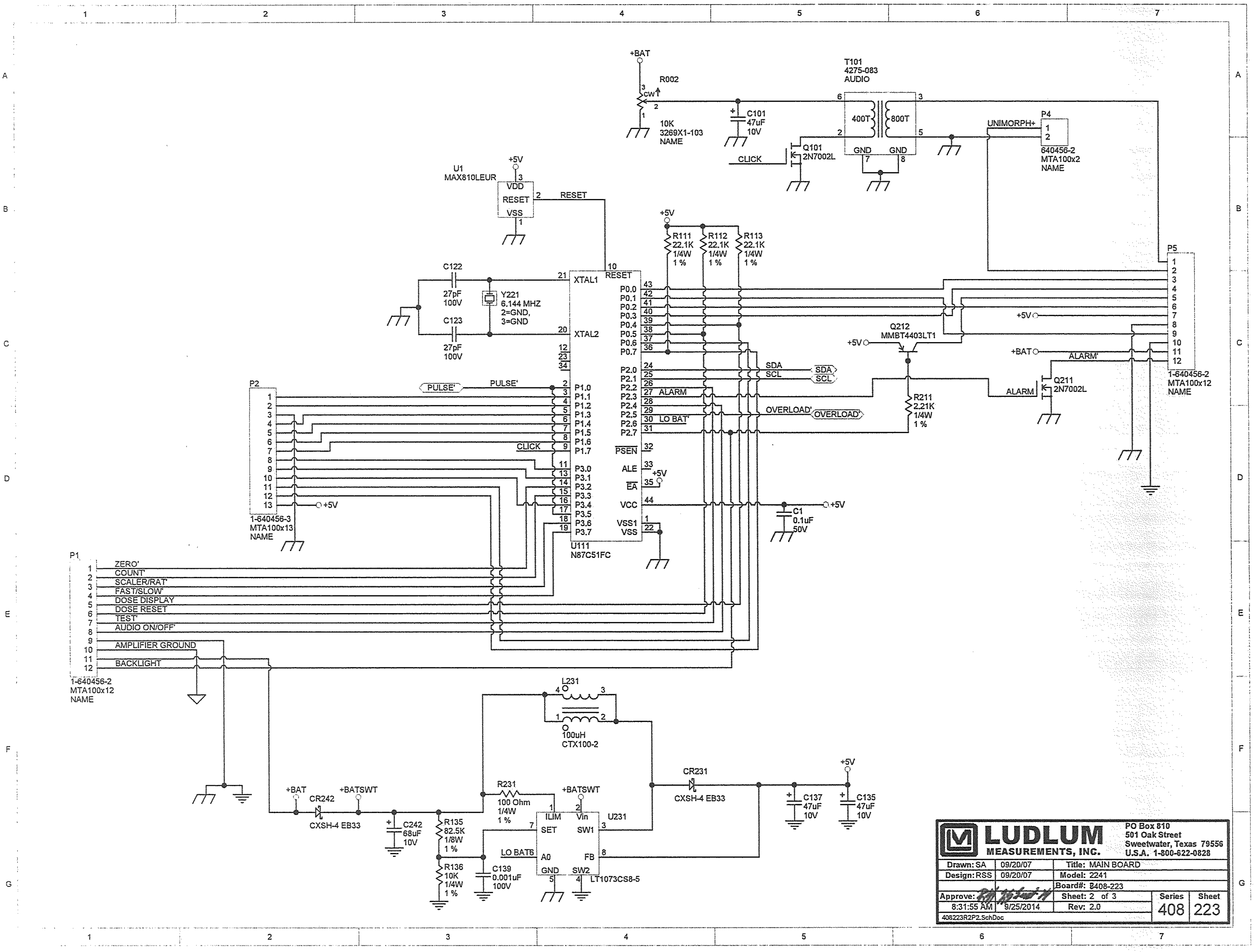
TITLE: SOURCE HOLDER ASSEMBLY

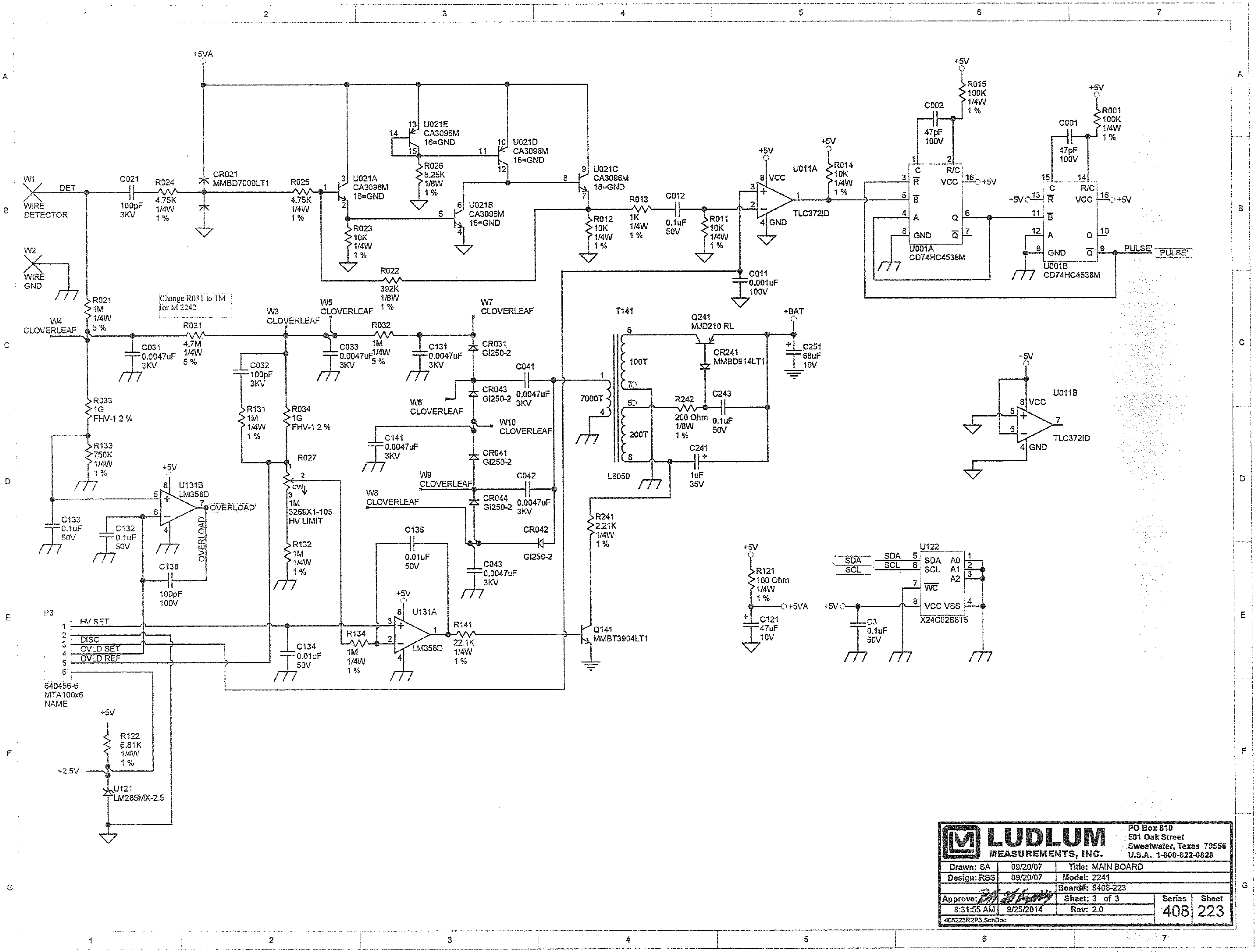
	SERIES	SHEET
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556	62	166B

VF

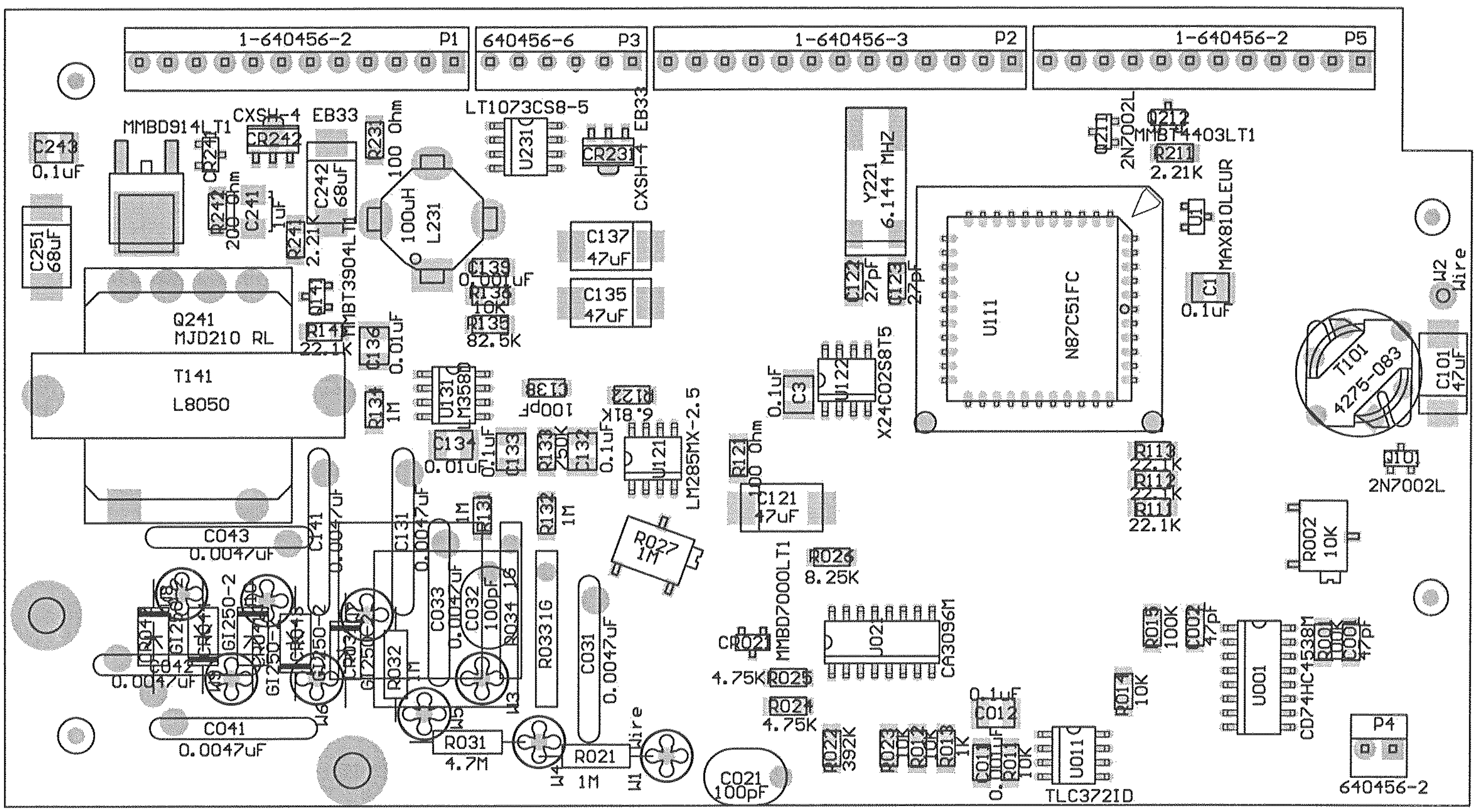


LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: SA	09/20/07	Title: MAIN BOARD	
Design: RSS	09/20/07	Model: 2241	
		Board#: 5408-223	
Approve:		Sheet: 1 of 3	Series 408 / Sheet 223
8:31:55 AM	9/25/2014	Rev: 2.0	
408223R2P1.SchDoc			


+BAT
R002
CW
10K
3269X1-103
NAME
C101
47uF
10V
T101
4275-083
AUDIO
400T
800T
GND
GND
Q101
2N7002L
CLICK
UNIMORPH+
P4
640456-2
MTA100x2
NAME
U1
MAX810LEUR
+5V
VDD
RESET
VSS
RESET
+5V
R111
22.1K
1/4W
1 %
R112
22.1K
1/4W
1 %
R113
22.1K
1/4W
1 %
P5
C122
27pF
100V
Y221
6.144 MHZ
2=GND,
3=GND
C123
27pF
100V
XTAL1
XTAL2
RESET
P0.0
P0.1
P0.2
P0.3
P0.4
P0.5
P0.6
P0.7
P2.0
P2.1
P2.2
P2.3
P2.4
P2.5
P2.6
P2.7
PSEN
ALE
EA
VCC
VSS1
VSS
U111
N87C51FC
SDA
SCL
ALARM
OVERLOAD'
LO BAT'
Q212
MMBT4403LT1
+5V
+BAT
ALARM'
Q211
2N7002L
ALARM
R211
2.21K
1/4W
1 %
1-640456-2
MTA100x12
NAME
P2
PULSE'
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
CLICK
P3.0
P3.1
P3.2
P3.3
P3.4
P3.5
P3.6
P3.7
1-640456-3
MTA100x13
NAME
C1
0.1uF
50V
P1
ZERO'
COUNT'
SCALER/RAT'
FAST/SLOW'
DOSE DISPLAY
DOSE RESET
TEST'
AUDIO ON/OFF'
AMPLIFIER GROUND
BACKLIGHT
1-640456-2
MTA100x12
NAME
L231
100uH
CTX100-2
CR231
CXSH-4 EB33
C137
47uF
10V
C135
47uF
10V
+BAT
CR242
CXSH-4 EB33
+BATSWT
C242
68uF
10V
R135
82.5K
1/8W
1 %
R136
10K
1/4W
1 %
C139
0.001uF
100V
R231
100 Ohm
1/4W
1 %
LO BAT6
ILIM
Vin
SET
SW1
A0
FB
GND
SW2
U231
LT1073CS8-5
LUDLUM
MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: SA 09/20/07
Design: RSS 09/20/07
Approve:
8:31:55 AM 9/25/2014
408223R2P2.SchDoc
Title: MAIN BOARD
Model: 2241
Board#: 8408-223
Sheet: 2 of 3
Rev: 2.0
Series 408
Sheet 223



W1
DET
WIRE DETECTOR
W2
WIRE GND
C021 100pF 3KV
R024 4.75K 1/4W 1 %
+5VA
CR021 MMBD7000LT1
R025 4.75K 1/4W 1 %
U021A CA3096M 16=GND
U021E CA3096M 16=GND
R026 8.25K 1/8W 1 %
U021D CA3096M 16=GND
U021B CA3096M 16=GND
U021C CA3096M 16=GND
R023 10K 1/4W 1 %
R022 392K 1/8W 1 %
R012 10K 1/4W 1 %
R013 1K 1/4W 1 %
C012 0.1uF 50V
R011 10K 1/4W 1 %
C011 0.001uF 100V
+5V
U011A
TLC372ID
VCC
GND
R014 10K 1/4W 1 %
C002 47pF 100V
R015 100K 1/4W 1 %
U001A CD74HC4538M
C001 47pF 100V
R001 100K 1/4W 1 %
U001B CD74HC4538M
PULSE'
R021 1M 1/4W 5 %
Change R031 to 1M for M 2242
W4 CLOVERLEAF
W3 CLOVERLEAF
W5 CLOVERLEAF
W7 CLOVERLEAF
C031 0.0047uF 3KV
R031 4.7M 1/4W 5 %
C033 0.0047uF 3KV
R032 1M 1/4W 5 %
C131 0.0047uF 3KV
CR031 GI250-2
C032 100pF 3KV
C041 0.0047uF 3KV
CR043 GI250-2
W6 CLOVERLEAF
W10 CLOVERLEAF
C141 0.0047uF 3KV
CR041 GI250-2
W9 CLOVERLEAF
C042 0.0047uF 3KV
W8 CLOVERLEAF
CR044 GI250-2
CR042 GI250-2
C043 0.0047uF 3KV
R033 1G FHV-1 2 %
R133 750K 1/4W 1 %
R131 1M 1/4W 1 %
R034 1G FHV-1 2 %
R027 1M 3269X1-105 HV LIMIT
CW
R132 1M 1/4W 1 %
U131B LM358D
OVERLOAD'
C133 0.1uF 50V
C132 0.1uF 50V
C138 100pF 100V
T141
100T
7000T
200T
L8050
Q241 MJD210 RL
CR241 MMBD914LT1
+BAT
C251 68uF 10V
R242 200 Ohm 1/8W 1 %
C243 0.1uF 50V
C241 1uF 35V
R241 2.21K 1/4W 1 %
Q141 MMBT3904LT1
U011B TLC372ID
C136 0.01uF 50V
U131A LM358D
R141 22.1K 1/4W 1 %
R134 1M 1/4W 1 %
C134 0.01uF 50V
P3
HV SET
DISC
OVLD SET
OVLD REF
640456-6 MTA100x6 NAME
R122 6.81K 1/4W 1 %
+2.5V
U121 LM285MX-2.5
R121 100 Ohm 1/4W 1 %
C121 47uF 10V
U122 X24C02S8T5
SDA
SCL
WC
A0 A1 A2
VCC VSS
C3 0.1uF 50V
LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: SA 09/20/07
Design: RSS 09/20/07
Approve:
8:31:55 AM 9/25/2014
408223R2P3.SchDoc
Title: MAIN BOARD
Model: 2241
Board#: 5408-223
Sheet: 3 of 3
Rev: 2.0
Series 408
Sheet 223



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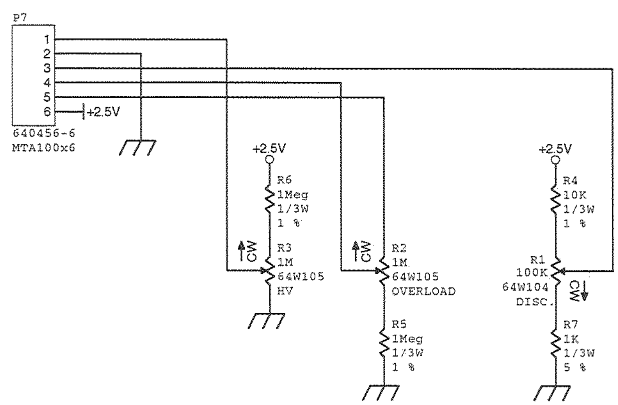
Design: RSS	01/12/05	
		Model: 2241
Approve: BSS	20 Jun 05	Board#: 5408-223
Layer: Mech.1 Mech.2 — MID: — 11:26:19 20-Jun-2005		Rev: 1.0 / SCALE: 1.50 — Series 408 — Sheet 224
BS408223		

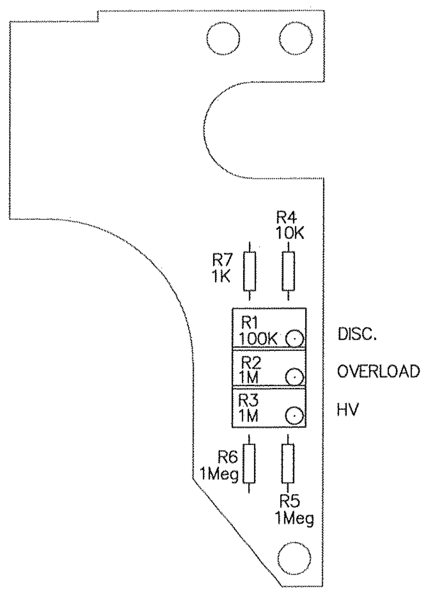


LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: CKB	30-Nov-99	Title: Calibration Board	
Design: LL	22-Mar-93	Model: 2240, 2241	
Check:		Board#: 5408-007	
Approve: JWS	14-Aug-05	Sheet: 0 of 0	Series 408
14:30:37	6-Jun-2005	Rev: 1.0	Sheet 12

408x12.sch



Drawn:	CKB	30-Nov-99	Title: Calibration Board		
Design:	LL	22-Mar-93			
Check:			Model: 2240, 2241		
Approve:	JWS	18-Aug-2005	Board#: 5408-007		
Layer: Mech.1	MID:		Rev: 1.0	Series	Sheet
	14:50:59	6-Jun-2005	SCALE: 1.00	408	13
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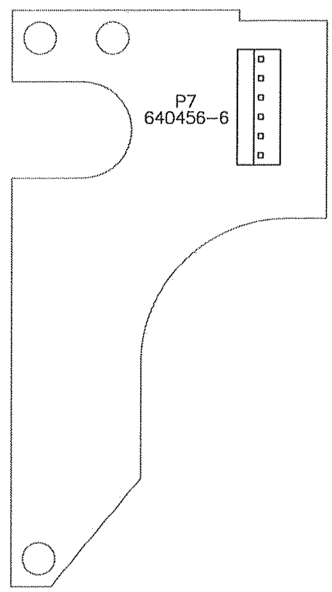
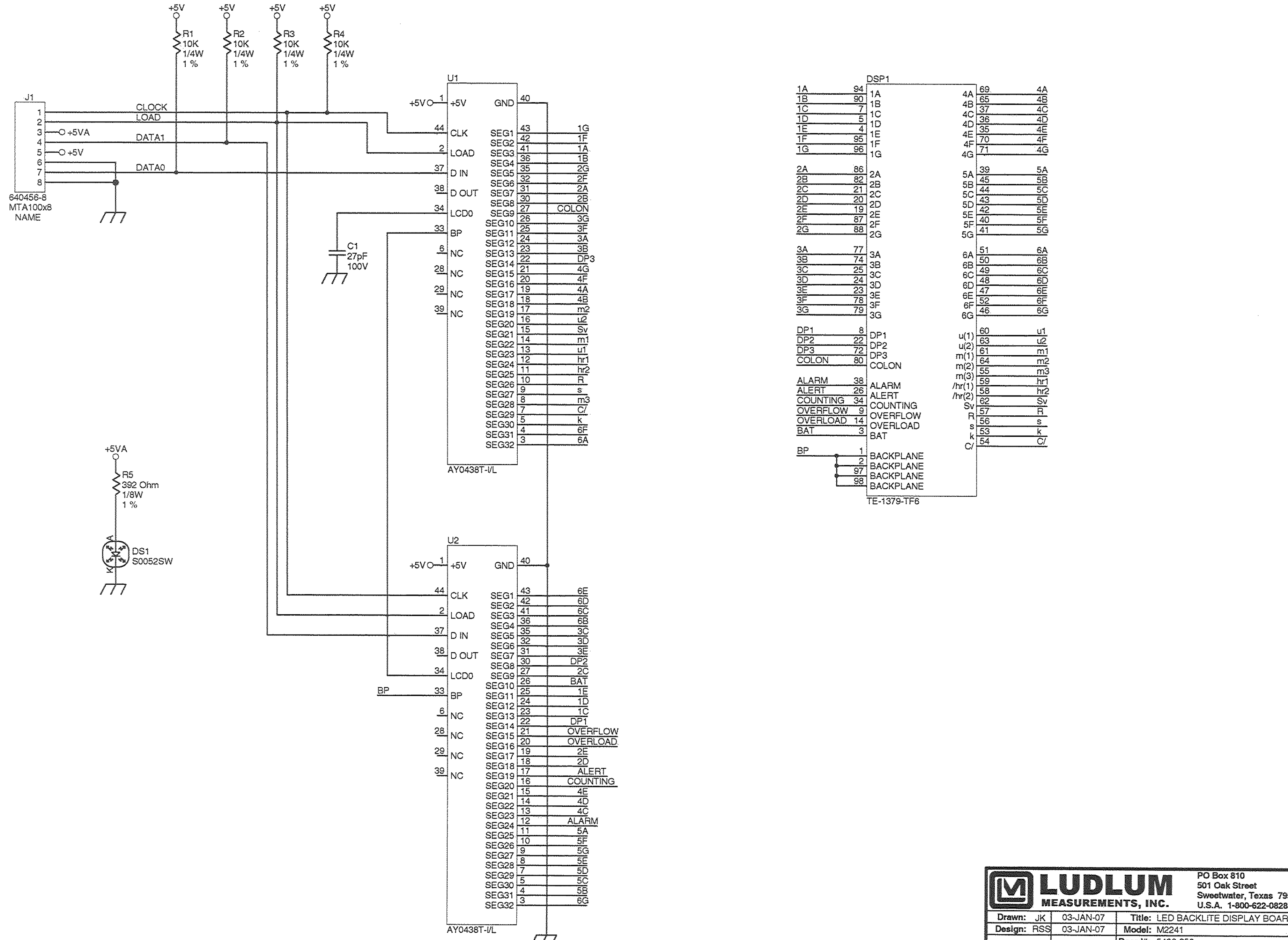
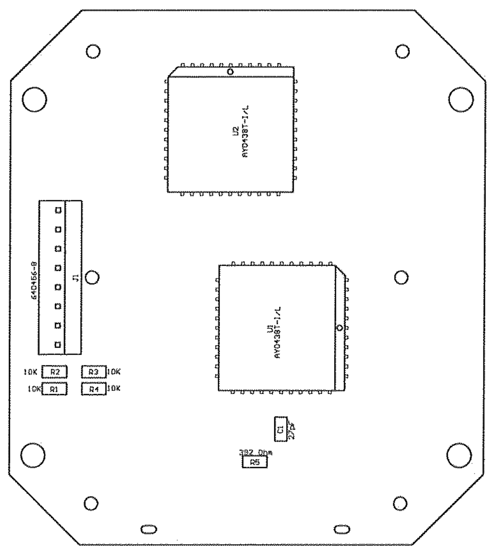


Drawn:	CKB	30–Nov–99	Title:		
Design:	LL	22–Mar–93	Calibration Board		
Check:			Model: 2240, 2241		
Approve:	JWS	18-Aug-2005	Board#: 5408–007		
Layer: Mech.1 Mech.2	BottomPaste P1 P2 P3 P4		Rev: 1.0	Series	Sheet
	MID: 1 2 3 4 5 6 7 8 9 10 11 12 13 14		SCALE: 1.00	408	13
	14:50:59	6–Jun–2005			
X:\Projects\LMI\M2240\m2240.Ddb\\Documents\5408–007\ref_LD\5408007.PCB					



LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn:	JK	03-JAN-07	Title: LED BACKLITE DISPLAY BOARD		
Design:	RSS	03-JAN-07	Model: M2241		
			Board#: 5408-259		
Approve:	RSS	24 May 07	Sheet: 1 of 1	Series	Sheet
13:12:20		24-May-2007	Rev: 2.0	408	259
408259R2P1.SCH					



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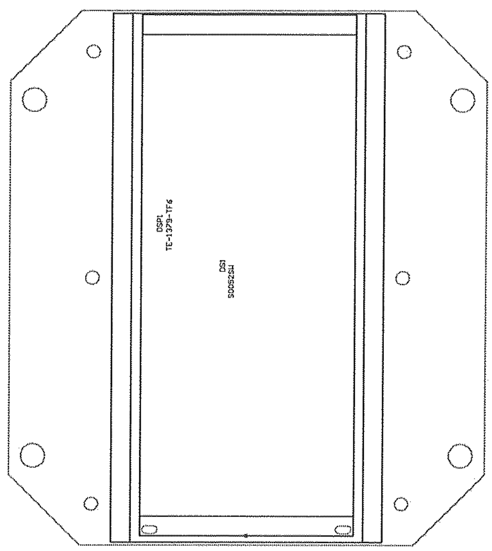
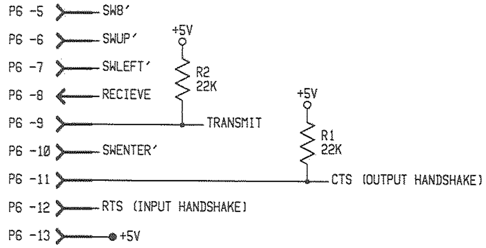
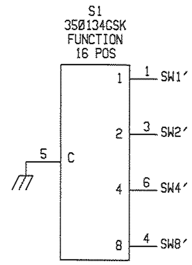
Design: RSS	23-FEB-07				
		Model: M2241			
Approve: RSS	24 May 07	Board#: 5408-259			
Layer:	MID: 13:15:16 24-May-2007	Rev: 2.0 SCALE: 1.00	Series 408	Sheet 260	
408259R2X1.PCB					



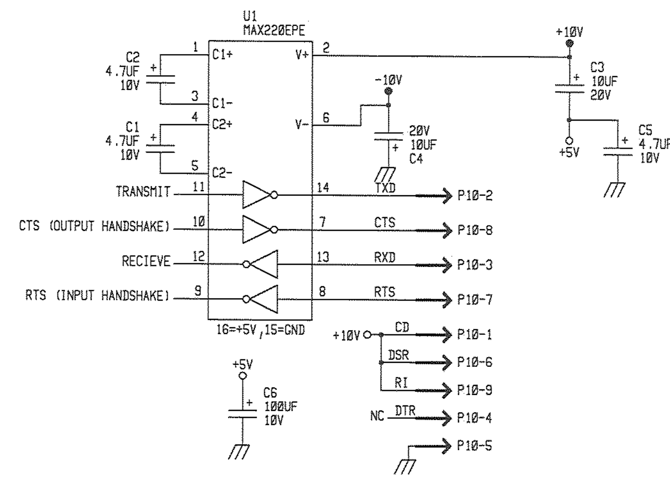
Drawn: JK	23-FEB-07	Title: LED BACKLITE DISPLAY BOARD		
Design: RSS	23-FEB-07			
		Model: M2241		
Approve: RS	24 May 07	Board#: 5408-259		
Layer:	MID: 13:15:16 24-May-2007	Rev: 2.0 SCALE: 1.00	Series 408	Sheet 260
408259R2X1.PCB				

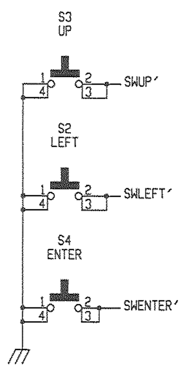
EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED





POS	FUNCTION
0	NORMAL OPERATION
1	DEAD TIME (us)
2	CALIBRATION CONSTANT
3	DISPLAY UNITS
4	TIMEBASE: CPS, CPM
5	AUDIO DIVIDE BY
6	RESPONSE TIME
7	RATEMETER ALARM / ALERT
8	SCALER ALARM / COUNT TIME
9	NOT USED
A	DETECTOR SETUP NUMBER
B	LCD BACKLIGHT ON TIME
C	SET MINIMUM DISPLAY
D	RS-232 DATA DUMP MODE
E	RS-232 DETECTOR SETUP MODE
F	RS-232 BAUD RATE





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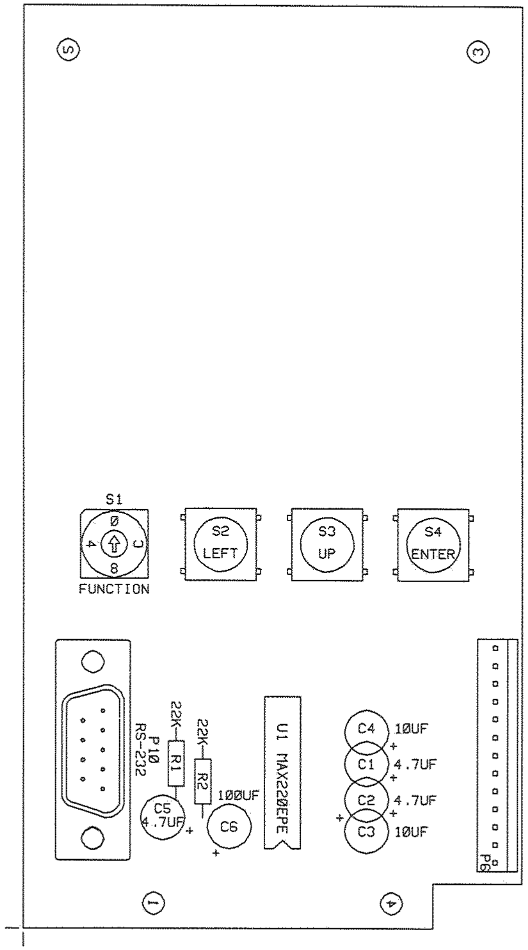
DR CKB		06/24/96
CHK	ESS	12-21-00
DSGN LL		3/17/93
APPD	RDS	21Dec00
NEXT HIGHER ASSY.		
09:54:25		21-Dec-00

LUDLUM MEASUREMENTS INC.

TITLE: SWITCH BOARD

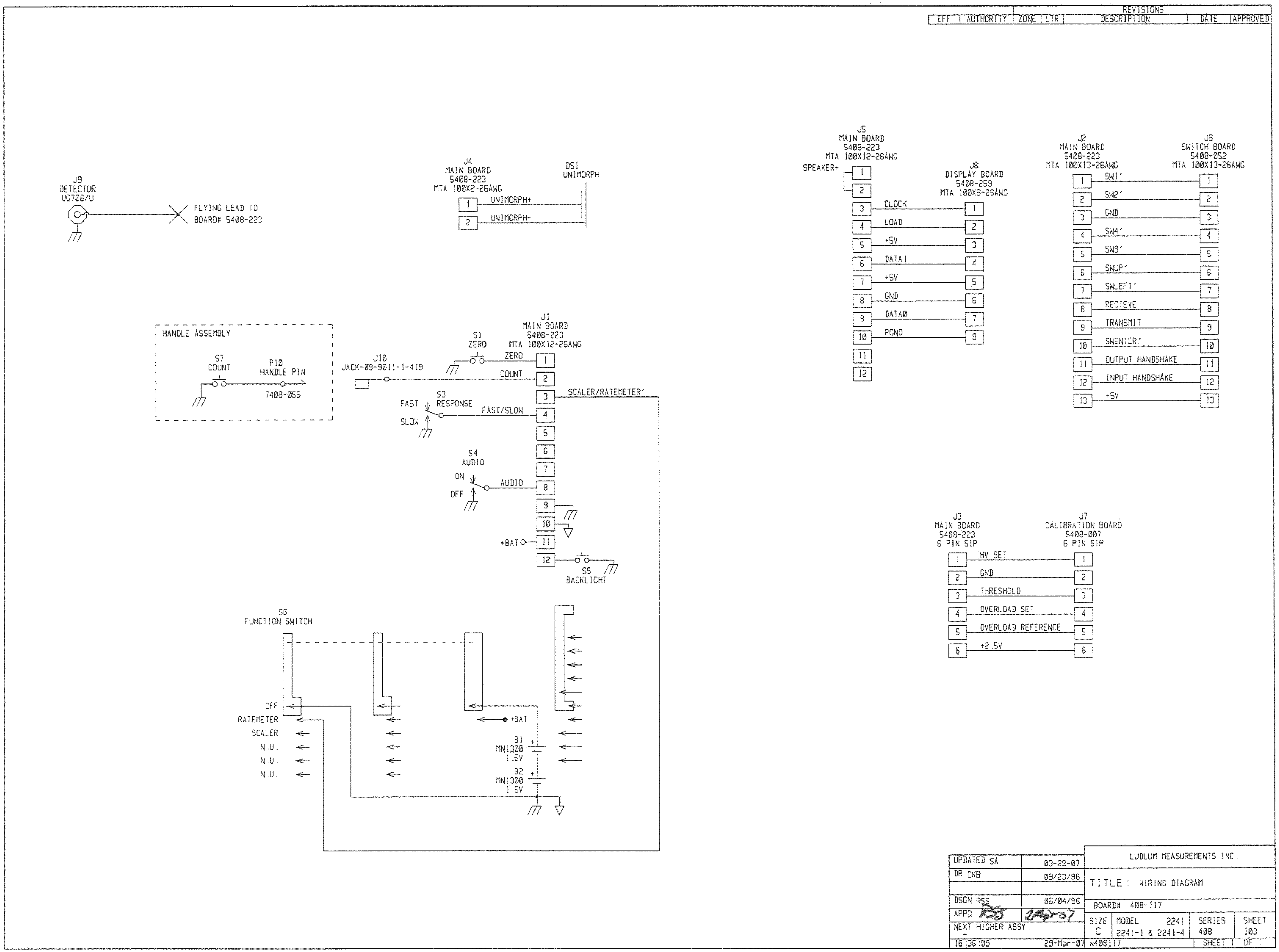
BOARD# 5400-052

SIZE	MODEL	SERIES	SHEET
C	2241	408	45
SB400052		SHEET 1	OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

DR	CKB	06/24/96	TITLE: SWITCH BOARD
CHK	RDS	12-21-00	BOARD: 5408-052
DSGN	LL	03/16/94	MODEL: 2241
APP	RDS	21 Dec 00	FILENAME: BS408052
COMPONENT		SOLDER	09:52:54 | 21-Dec-00
OUTLINE		OUTLINE	REVISION 1.0 | SERIES 408 | SHEET 46


REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
J9
DETECTOR
UG706/U
FLYING LEAD TO
BOARD# 5408-223
J4
MAIN BOARD
5408-223
MTA 100X2-26AWG
UNIMORPH+
UNIMORPH-
DS1
UNIMORPH
J5
MAIN BOARD
5408-223
MTA 100X12-26AWG
SPEAKER+
CLOCK
LOAD
+5V
DATA1
+5V
GND
DATA0
PGND
J8
DISPLAY BOARD
5408-259
MTA 100X8-26AWG
J2
MAIN BOARD
5408-223
MTA 100X13-26AWG
SW1'
SW2'
GND
SW4'
SW8'
SWUP'
SWLEFT'
RECIEVE
TRANSMIT
SWENTER'
OUTPUT HANDSHAKE
INPUT HANDSHAKE
+5V
J6
SWITCH BOARD
5408-052
MTA 100X13-26AWG
HANDLE ASSEMBLY
S7
COUNT
P10
HANDLE PIN
7408-055
J10
JACK-09-9011-1-419
S1
ZERO
ZERO
COUNT
J1
MAIN BOARD
5408-223
MTA 100X12-26AWG
SCALER/RATEMETER'
FAST
S3
RESPONSE
FAST/SLOW
SLOW
S4
AUDIO
ON
AUDIO
OFF
+BAT
S5
BACKLIGHT
J3
MAIN BOARD
5408-223
6 PIN SIP
HV SET
GND
THRESHOLD
OVERLOAD SET
OVERLOAD REFERENCE
+2.5V
J7
CALIBRATION BOARD
5408-007
6 PIN SIP
S6
FUNCTION SWITCH
OFF
RATEMETER
SCALER
N.U.
N.U.
N.U.
+BAT
B1
MN1300
1.5V
B2
MN1300
1.5V
UPDATED SA 03-29-07
DR CKB 09/23/96
DSGN RSS 06/04/96
APPD RSS 2-Apr-07
NEXT HIGHER ASSY.
16:36:09 29-Mar-07
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
BOARD# 408-117
SIZE C
MODEL 2241
2241-1 & 2241-4
SERIES 408
SHEET 103
W408117
SHEET 1 OF 1

Appendix A

RS-232 Output Formats

The Ludlum Model 2241 series of instruments has an RS-232 serial communications port that can be used to log readings and read or set instrument parameters. There are two formats available. Most Model 2241 instruments have the binary format outlined below, but some newer Model 2241-2 units have an ASCII output, which is also outlined below following the binary format explanation.

The RS-232 port is configured at 9600 baud, 8 data bits, no parity, and 1 stop bit (9600,8,N,1). Ludlum Measurements can supply a Windows-based software that can be used to help calibrate the instruments, but note that it will not communicate with the newer ASCII output Model 2241-2 units.

Binary Output Format (15 Bytes)

BYTE01	RatemeterCPS+0	MSB
BYTE02	RatemeterCPS+1	
BYTE03	RatemeterCPS+2	
BYTE04	RatemeterCPE+3	LSB
BYTE05	Scaler+0	MSB
BYTE06	Sclaer+1	
BYTE07	Scaler+2	
BYTE08	Scaler+3	
BYTE09	Scaler+4	LSB
BYTE10	CountTime+0	MSB
BYTE11	CountTime+1	LSB
BYTE12	CountTimeLeft+0	MSB
BYTE13	CountTimeLeft+1	LSB
BYTE14	Carriage Return (0DH)	
BYTE15	Line Feed (0AH)	

The ratemeter value is in cps and is scaled by a factor of 256. To get the ratemeter reading in cpm, take the value and divide by 256, and then multiply by 60.

RS-232 Commands
E – auto dump off

A – auto dump on

C – start scaler

F – set scaler count time

R – send parameters from instrument to computer

S – read parameters from computer to instrument

O – output once

All commands must be sent in upper case laters.

Output of "R" Command – Read Parameters

BYTE01	Detector+0	
BYTE02	DeadConstant+0	MSB
BYTE03	DeadConstant+1	LSB
BYTE04	CaConstant+0	MSB
BYTE05	CalConstant+1	
BYTE06	CalConstant+2	
BYTE07	CalConstant+3	
BYTE08	CalConstant+4	
BYTE09	CalConstant+5	LSB
BYTE10	RateAlarm+0	MSB
BYTE11	RateAlarm+1	
BYTE12	RateAlarm+2	
BYTE13	RateAlarm+3	
BYTE14	RateAlarm+4	LSB
BYTE15	ScalerAlarm+0	MSB
BYTE16	ScalerAlarm+1	
BYTE17	ScalerAlarm+2	
BYTE18	ScalerAlarm+3	
BYTE19	ScalerAlarm+4	LSB
BYTE20	CountTime+0	MSB
BYTE21	CountTime+1	LSB
BYTE22	Units+0	
BYTE23	TimeBase+0	
BYTE24	AudioDivideBy+0	
BYTE25	Response+0	
BYTE26	RateAlert+0	MSB
BYTE27	RateAlert+1	
BYTE28	RateAlert+2	
BYTE29	RateAlert+3	
BYTE30	RateAlert+4	LSB
BYTE31	CheckSource+0	MSB
BYTE32	CheckSource+1	
BYTE33	CheckSource+2	

BYTE34	CheckSource+3	
BYTE35	CheckSource+4	LSB
BYTE36	PercentCS+0	
BYTE37	MinDisplay+0	
BYTE38	Carriage Return (0DH)	
BYTE39	Line Feed (0AH)	

Input of "S" Command – Send Parameters

BYTE1	DeadCosntant+0	MSB
BYTE2	DeadConstant+1	LSB
BYTE3	CalConstant+0	MSB
BYTE4	CalConstant+1	
BYTE5	CalConstant+2	
BYTE6	CalCosntant+3	
BYTE7	CalConstant+4	
BYTE8	CalConstant+5	LSB
BYTE9	RateAlarm+0	MSB
BYTE10	RateAlarm+1	
BYTE11	RateAlarm+2	
BYTE12	RateAlarm+3	
BYTE13	RateAlarm+4	LSB
BYTE14	ScalerAlarm+0	MSB
BYTE15	ScalerAlarm+1	
BYTE16	ScalerAlarm+2	
BYTE17	ScalerAlarm+3	
BYTE18	ScalerAlarm+4	LSB
BYTE19	CountTime+0	MSB
BYTE20	CountTime+1	LSB
BYTE21	Units+0	
BYTE22	TimeBase+0	
BYTE23	AudioDivdeBy+0	
BYTE24	Response+0	
BYTE25	RateAlert+0	MSB
BYTE26	RateAlert+1	
BYTE27	RateAlert+2	
BYTE28	RateAlert+3	
BYTE29	RateAlert+4	LSB
BYTE30	CheckSource+0	MSB
BYTE31	CheckSource+1	
BYTE32	CheckSource+2	
BYTE33	CheckSource+3	
BYTE34	CheckSource+4	LSB
BYTE35	PercentCS+0	
BYTE36	MinDisplay+0	

Input of "F" Command – Set Count Time

BYTE1	CountTime+0	MSB
BYTE2	CountTime+1	LSB

Units 0 = R
1 = Sv
2 = cpm

Timebase 0 = min
1 = seconds

AudioDivide 0 = Auto
1 = Manual

ASCII Output Format

This special firmware changes the format of the auto-dump from binary to ASCII. The output interval remains the same (2 seconds).

2241	Special Firmware 40804n10	08/06/2003
2241-2	Special Firmware 40806n13	04/04/2003
2241-3	Special Firmware 40806n16	07/07/2004

The old format was (binary):

Byte 1	Ratemeter CPS + 0
Byte 2	Ratemeter CPS + 1
Byte 3	Ratemeter CPS + 2
Byte 4	Ratemeter CPS + 3
Byte 5	Scaler + 0
Byte 6	Scaler + 1
Byte 7	Scaler + 2
Byte 8	Scaler + 3
Byte 9	Scaler + 4
Byte 10	Count Time + 0
Byte 11	Count Time + 1
Byte 12	Count Time Left + 0
Byte 13	Count Time Left + 1
Byte 14	Carriage Return (0DH)
Byte 15	Line Feed (0AH)

and is now replaced with (ASCII):

byte 1	x	Ratemeter
byte 2	x	Ratemeter
byte 3	x	Ratemeter
byte 4	x	Ratemeter
byte 5	x	Ratemeter
byte 6	y	Display units
byte 7	Carriage Return (0DH)	

byte 8	Line Feed (0AH)

The ratemeter is displayed as 5 ASCII digits with a decimal, if necessary, and matches the LCD display on the 2241-2.
The display mode is a value from 0 to 9 representing the display units.

CPS	0
KCPS	1
CPM	2
KCPM	3
µR	4
mR	5
R	6
µSv	7
mSv	8
Sv	9

Note: The LMI Model 2241 calibration software is not compatible with this firmware version.

Example output:

02.991	(=2.99 kcps)
01.801	(=1.80 kcps)
01.221	(=1.22 kcps)
00.831	(=0.83 kcps)
00.581	(=0.58 kcps)
004160	(=416 cps)

ATTACHMENT C

Fluke 451P Ion Chamber Survey Meter Operators Manual

Biomedical

451P

Ion Chamber Survey Meter

Operators Manual

PN FBC-0059
September 2013, Rev. 1

Warranty and Product Support

Fluke Biomedical warrants this instrument against defects in materials and workmanship for one full year from the date of original purchase. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective, provided you return the product, shipping prepaid, to Fluke Biomedical. This warranty does not apply if the product has been damaged by accident or misuse or as the result of service or modification by other than Fluke Biomedical. IN NO EVENT SHALL FLUKE BIOMEDICAL BE LIABLE FOR CONSEQUENTIAL DAMAGES.

Only serialized products and their accessory items (those products and items bearing a distinct serial number tag) are covered under this one-year warranty. PHYSICAL DAMAGE CAUSED BY MISUSE OR PHYSICAL ABUSE IS NOT COVERED UNDER THE WARRANTY. Items such as cables and nonserialized modules are not covered under this warranty.

Recalibration of instruments is not covered under the warranty.

This warranty gives you specific legal rights, and you may also have other rights which vary from state to state, province to province, or country to country. This warranty is limited to repairing the instrument to Fluke Biomedical's specifications.

Notices

All Rights Reserved

Copyright Release

Unpacking and Inspection

Follow standard receiving practices upon receipt of the instrument. Check the shipping carton for damage. If damage is found, stop unpacking the instrument. Notify the carrier and ask for an agent to be present while the instrument is unpacked. There are no special unpacking instructions, but be careful not to damage the instrument when unpacking it. Inspect the instrument for physical damage such as bent or broken parts, dents, or scratches.

Technical Support

For application support or answers to technical questions, either email techservices@flukebiomedical.com or call 1-800- 850-4608 or 1-440-248-9300. In Europe, email techsupport.emea@flukebiomedical.com or call +31-40-2965314.

Claims

Our routine method of shipment is via common carrier, FOB origin. Upon delivery, if physical damage is found, retain all packing materials in their original condition and contact the carrier immediately to file a claim. If the instrument is delivered in good physical condition but does not operate within specifications, or if there are any other problems not caused by shipping damage, please contact Fluke Biomedical or your local sales representative.

Returns and Repairs

Return Procedure

All items being returned (including all warranty-claim shipments) must be sent freight-prepaid to our factory location. When you return an instrument to Fluke Biomedical, we recommend using United Parcel Service, Federal Express, or Air Parcel Post. We also recommend that you insure your shipment for its actual replacement cost. Fluke Biomedical will not be responsible for lost shipments or instruments that are received in damaged condition due to improper packaging or handling.

Use the original carton and packaging material for shipment. If they are not available, we recommend the following guide for repackaging:

- Use a double–walled carton of sufficient strength for the weight being shipped.
- Use heavy paper or cardboard to protect all instrument surfaces. Use nonabrasive material around all projecting parts.
- Use at least four inches of tightly packed, industry-approved, shock-absorbent material around the instrument.

Returns for partial refund/credit:

Every product returned for refund/credit must be accompanied by a Return Material Authorization (RMA) number, obtained from our Order Entry Group at 1-440-498-2560.

Repair and calibration:

To find the nearest service center, go to www.flukebiomedical.com/service or

In the U.S.A.:
Cleveland Calibration Lab
Tel: 1-800-850-4608 x2564
Email: globalcal@flukebiomedical.com

Everett Calibration Lab
Tel: 1-888-99 FLUKE (1-888-993-5853)
Email: service.status@fluke.com

In Europe, Middle East, and Africa:
Eindhoven Calibration Lab
Tel: +31-40-2675300
Email: ServiceDesk@fluke.com

In Asia:
Everett Calibration Lab
Tel: +425-446-6945
Email: service.international@fluke.com

To ensure the accuracy of the Product is maintained at a high level, Fluke Biomedical recommends the product be calibrated at least once every 12 months. Calibration must be done by qualified personnel. Contact your local Fluke Biomedical representative for calibration.

Certification

This instrument was thoroughly tested and inspected. It was found to meet Fluke Biomedical's manufacturing specifications when it was shipped from the factory. Calibration measurements are traceable to the National Institute of Standards and Technology (NIST). Devices for which there are no NIST calibration standards are measured against in-house performance standards using accepted test procedures.

WARNING

Unauthorized user modifications or application beyond the published specifications may result in electrical shock hazards or improper operation. Fluke Biomedical will not be responsible for any injuries sustained due to unauthorized equipment modifications.

Restrictions and Liabilities

Information in this document is subject to change and does not represent a commitment by Fluke Biomedical. Changes made to the information in this document will be incorporated in new editions of the publication. No responsibility is assumed by Fluke Biomedical for the use or reliability of software or equipment that is not supplied by Fluke Biomedical, or by its affiliated dealers.

Manufacturing Location

The 451P Ion Chamber Survey Meter is manufactured at Fluke Biomedical, 6920 Seaway Blvd., Everett, WA, U.S.A.

Table of Contents

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Introduction

The Model 451P Ion Chamber Survey Meter (the Survey Meter) is a hand-held, pressurized, battery operated meter designed to measure gamma and x-ray radiation above 25 keV, and beta radiation above 1 MeV, using the latest CMOS and LCD technology. The Survey Meter case is constructed of high strength ABS plastic. A gasket seals moisture out of the Survey Meter and provides a cushion for the internal components. The readout consists of a 2½ digit liquid crystal display and a 100 segment analog bar graph. The bar graph contains a zero segment and twenty groups of five segments each. A permanent scale is located on the display screen. The major divisions of the scale indicate the units corresponding to the range that the meter is measuring. The units of measurement show next to the 2½ digit display. LOW BAT and FREEZE appear on the display when the Survey Meter is operating in these modes. External controls consist of an ON/OFF button and a MODE button. The Survey Meter is auto-ranging and auto-zeroing. The auto-on circuit for the backlight is enabled when twilight conditions occur. An internal factory-set alarm blinks the display if the rate exceeds 5 R/hr. Two 9 volt batteries, located in the rear of the Survey Meter, provide over 200 hours of continuous operation.

Intended Use

The 451P Ion Chamber Survey Meter is a hand-held, pressurized, battery operated unit designed to measure gamma and x-ray radiation above 25 keV and beta radiation above 1 MeV.

Safety Information

A **Warning** identifies conditions and procedures that are dangerous to the user. A **Caution** identifies conditions and procedures that can cause damage to the Product or the equipment under test.

Table 1 is a list of symbols used on the product and in this manual.

Table 1. Symbols

Symbol	Description	Symbol	Description
□	Hazardous voltage. Risk of electric shock.	□	Risk of Danger. Important information. See Manual.
□	DC (Direct Current)	□	On/Off button
□	This product complies with the WEEE Directive (2002/96/EC) marking requirements. The affixed label indicates that you must not discard this electrical/electronic product in domestic household waste. Product Category: With reference to the equipment types in the WEEE Directive Annex I, this product is classed as category 9 "Monitoring and Control Instrumentation" product. Do not dispose of this product as unsorted municipal waste. Go to Fluke's website for recycling information.	□	This product contains a Lithium-ion battery. Do not mix with solid waste stream. Spent batteries should be disposed of by a qualified recycler or hazardous materials handler per local regulations. Contact your authorized Fluke Service Center for recycling information.
□	Conforms to European Union directives		

□ □ Warning

To prevent possible electrical shock, fire, or personal injury:

Read all safety information before you use the Product.

Use the Product only as specified, or the protection supplied by the Product can be compromised.

Remove the batteries if the Product is not used for an extended period of time, or if stored in temperatures above 50 °C. If the batteries are not removed, battery leakage can damage the Product.

The battery door must be closed and locked before you operate the Product.

Replace the batteries when the low battery indicator shows to prevent incorrect measurements.

Comply with local and national safety codes. Use personal protective equipment.

Carefully read all instructions.

Do not touch voltages > 30 V ac rms, 42 V ac peak, or 60 V dc.

Do not use the Product around explosive gas, vapor, or in damp or wet environments.

Do not use and disable the Product if it is damaged.

Do not use the Product if it operates incorrectly.

Examine the case before you use the Product. Look for cracks or missing plastic.

Use this Product indoors only.

Remove all accessories before the battery door is opened.

If the device shows a relatively high radiation rate, it is possible that the Product was contaminated. Be careful when you replace or work on this Product. High radiation rates can quickly cause the cumulative exposure of the operator to increase, which increases the risk of injury.

The check source contains radioactive materials, used for the verification of the survey meter operation. Be careful when you use and store the check source.

Each person who uses a product that senses and measures ionizing radiation must:

- **Be approved to do work where there is radiation**
- **Obey all applicable safety procedures and regulations**
- **Be approved to correctly interpret the indications on the product**

The user of this Product must read and strictly obey the instructions and precautions contained in the manuals. If you do not obey the instructions and precautions, there is a risk of injury. If you do not obey the instructions and precautions there is a risk that the Product will show incorrect indications. Before each use, do a battery check and other preoperational checks to make sure that the Product operates correctly.

hms01.eps

Figure 1. Fluke 451P Ion Chamber Survey Meter

Features

The following sections describe the features of the Survey Meter.

Overrange Rate

If the instantaneous radiation rate measured by the Survey Meter exceeds 5 R/h, the 'R' in 'mR/h' or the 'Sv' in 'Sv/h' displayed will blink to notify the user that a potential error in the integrated radiation value exists. The blinking will stop when the integrated value is cleared. This, however, may also clear the log data RAM.

Low Battery Indicator

There are about 6 hours of operation remaining when the LOW BATTERY indicator first becomes visible. When the LOW BATTERY indicator blinks, there is less than 1 hour of operation remaining. These times are for two batteries installed and from the first occurrences of these indications. If the Survey Meter is turned off during a low battery condition, the batteries will recover somewhat, but time of operation remaining will be less. The LCD low battery indicator is disabled during communication mode. Be sure to use fresh batteries when calibrating the Survey Meter.

Warning

For safe operation and maintenance of the product, note the chamber bias from the self-test. If chamber bias is LO, the Product cannot measure high radiation rates accurately. The Product requires service, contact Fluke.

Verify the chamber bias is low. Turn off the Survey Meter and replace with new 9 volt batteries. Turn on the Survey Meter. After the self-test, if blinking low battery reoccurs, the bias is low.

Warm-up Time

The pressured ion chamber collection potential is 105 Vdc and is derived from the 5 lithium cells. The warm-up time for a Survey Meter that has been off 12 hours or more is about 4 minutes for readings less than 20 °R/h in a 10 μR/h or less background.

Specifications

Radiation Detected .... Beta above 1 MeV & gamma above 25 KeV

Operating Ranges .... 0 µR/hr to 500 µR/hr (0 µSv/h to 5 µSv/h), 0 mR/h to 5 mR/h (0 µSv/h to 50 µSv/h) 0 mR/h to 50 mR/h (0 µSv/h to 500 µSv/h), 0 mR/h to 500 mR/h (0 mSv/h to 5 mSv/h), 0 R/h to 5 R/h (0 mSv/h to 50 mSv/h)

Accuracy .... ± 10 % of reading between 10 % and 100 % of full-scale indication on any range, exclusive of energy response (calibration source is 137 Cs)

Detector .... 230 cc active volume air ionization chamber, pressurized to 8 atmospheres. Plastic chamber wall 200 mg/cm2 thick

Warm-Up Time .... Less than one minute for initial operation when the instrument is in temperature equilibrium with the surrounding area and about 4 minutes for readings less than 20 µR/h in a 10 µR/h or less background.

Drift .... After seven minutes operation, 0.04 mR/h equivalent, or less

Response Time .... Time measured from 10 % to 90 % of final value for a step increase/decrease in radiation rate such that a range change does not occur:

0 µR/h to 500 µR/h (0 µSv/h to 5 µSv/h) range: 5 seconds. 0 mR/hr to 5 mR/hr (0 µSv/h to 50 µSv/h) range: 2 seconds. 0 mR/h to 50 mR/h (0 µSv/h to 500 µSv/h) range: 1.8 seconds. 0 mR/h to 500 mR/h (0 mSv/h to 5 mSv/h) range: 1.8 seconds. 0 R/h to 5 R/h (0 mSv/h to 50 mSv/h) range: 1.8 seconds.
NOTE: In pulsating field, the instantaneous rate should not exceed 5 R/h for proper integration; instantaneous exposure rate is still limited to 5 R/h

Precision .... Within 5 % reading

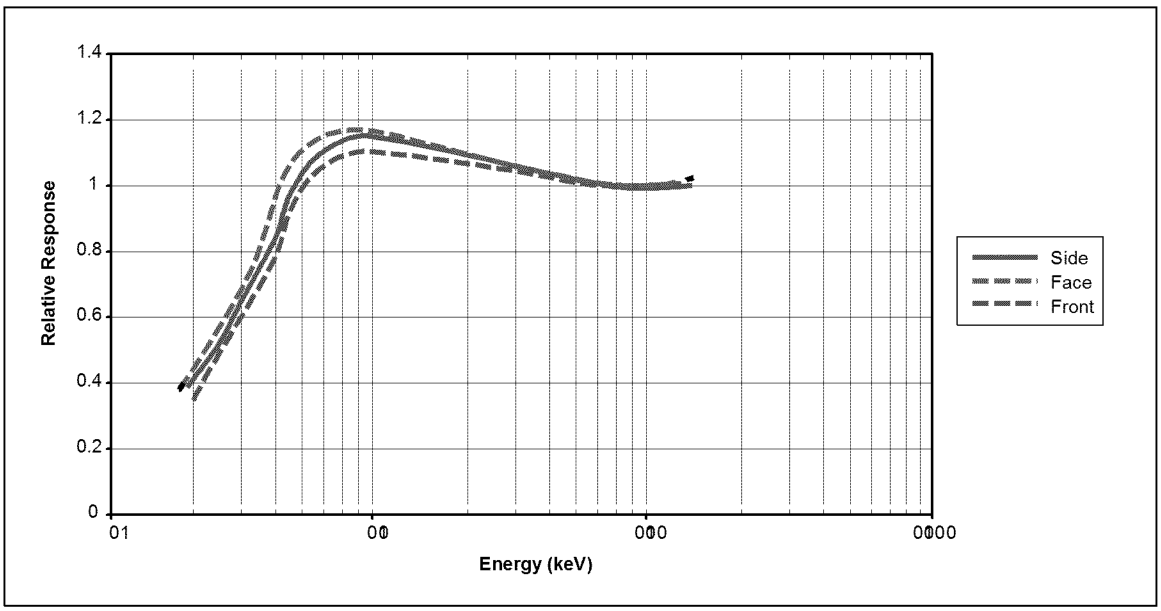
Readout .... Liquid Crystal Display: contains an analog bar graph with a permanent scale on the display and a 2½ digit display. Analog Display: the bar graph consists of 100 segments, 2½ inches long; the scale has five major divisions; the appropriate value for the operating range of the instrument will appear below the scale. Digital Display: the digital display is 2½ digits followed by a significant zero digit depending on the operating range of the instrument. The leading ½ digit is blank, or a "1" or a "0" for clarity. Units of measure appear to the right of the digital display. Appropriate multipliers also appear on the display
Units: as indicated under Range, programmable in R/h or Sv/h. Appropriate multipliers also appear on the display. Auto-On Backlight: turns on when ambient light is less then twilight conditions.

External Controls .... ON/OFF button, MODE button

Automatic Features .... Ranging and zeroing are fully automatic.

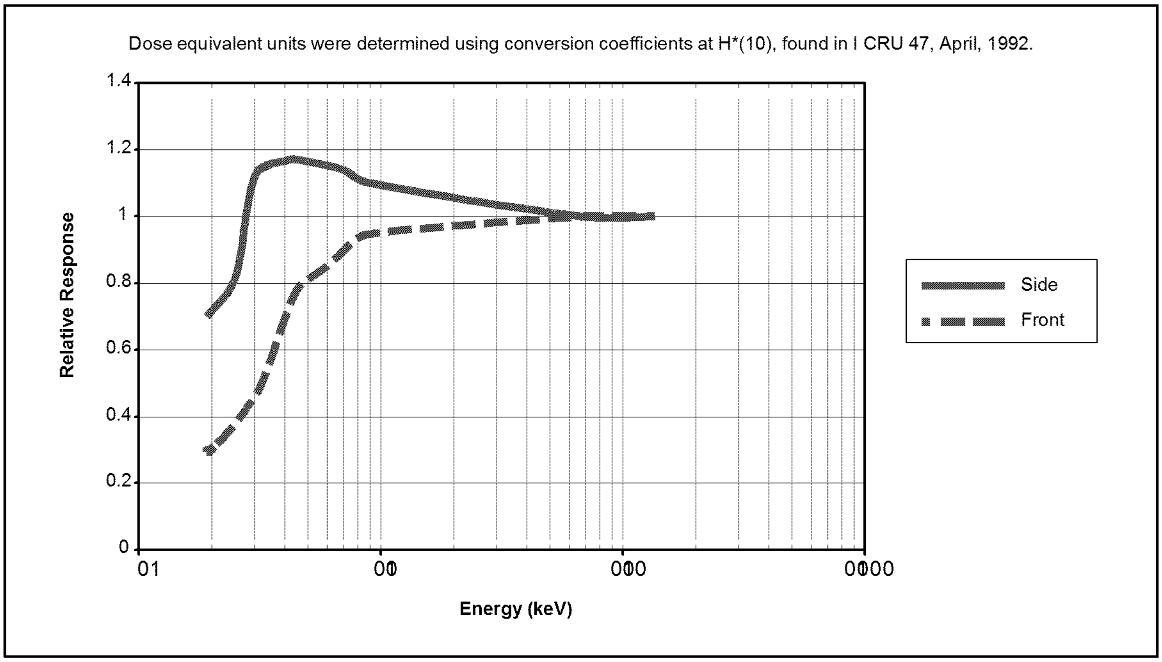
Environmental	Operating Temperature Range: -4 °F to +122 °F (-20 °C to +50 °C) Relative Humidity Range: 0 % to 95 %, non-condensing Geotropism: less than 1 % Altitude 2000 m For Indoor Use
Dimensions (L x W x H)	8.5 in x 4.5 in x 8.6 in (21 cm x 11.4 cm x 21.3 cm)
Weight	Approximately 2.6 lb (1.2 kg)
Batteries	Two 9-volt batteries (NEDA 1604A or 6LR61 or 6AM6) provide over 200 hours continuous operation.
IP Rating	IEC 60529: IP40
Safety	IEC 61010-1: Pollution Degree 2
Electromagnetic Environment	IEC 61326-1: Portable
Emissions Classification	IEC CISPR 11: Group 1, Class A. *Group 1 ISM equipment*: group 1 contains all ISM equipment in which there is intentionally generated and/or used conductively coupled radio-frequency energy which is necessary for the internal functioning of the equipment itself. *Class A equipment* is equipment suitable for use in all establishments other than domestic and those directly connected to a low voltage power-supply network which supplies buildings used for domestic purposes.

* Specifications are subject to change without notice.



hms06.eps

Figure 2. Model 451P Typical Energy Response



hms05.eps

Figure 3. Model 451P DE SI Typical Energy Dependence

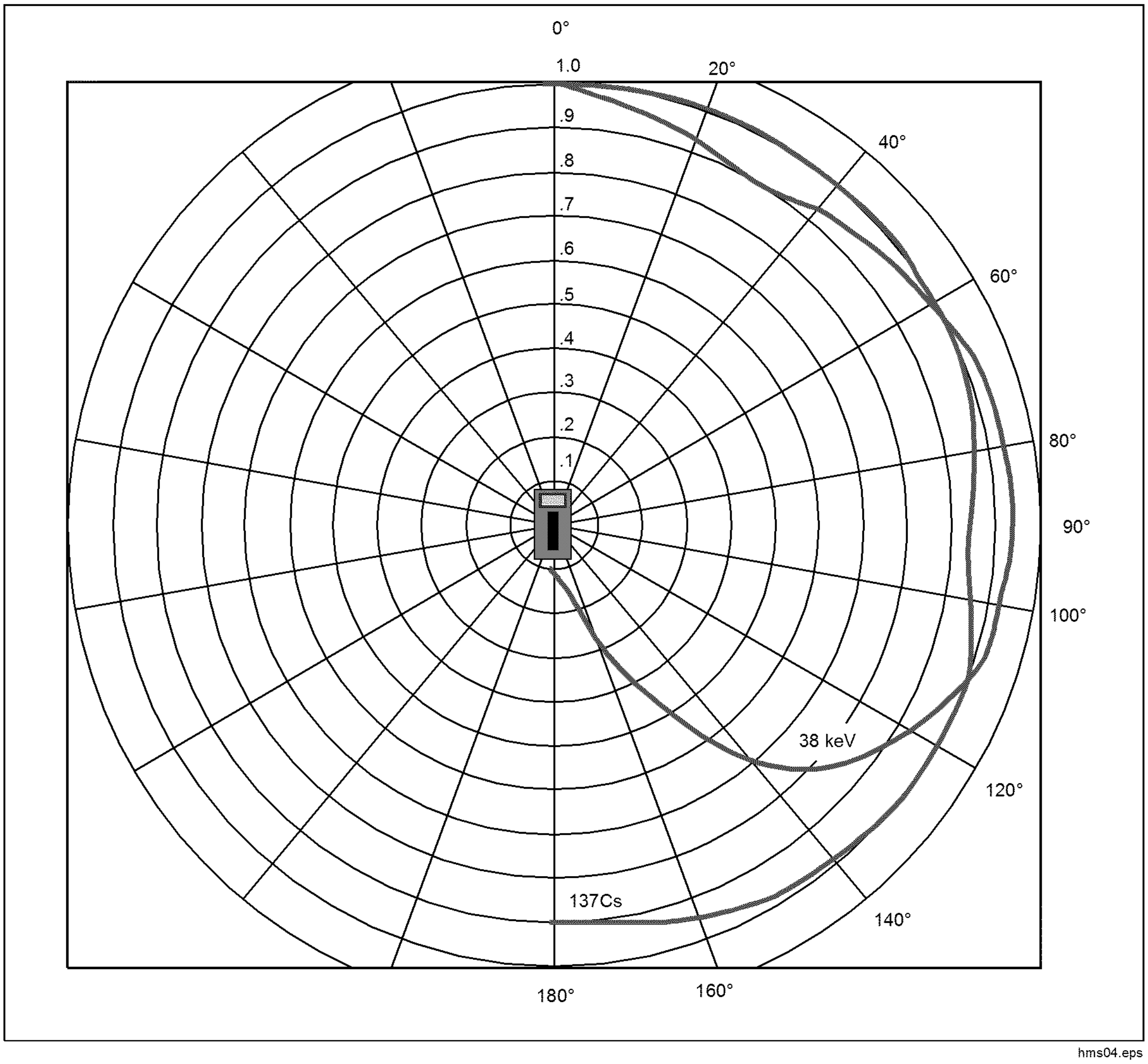


Figure 4. Survey Meter Angular Response

Receiving Inspection

Upon receipt of the Survey Meter:

1. Check the shipping cartons(s) and their contents for in-shipment damage.
2. Check that all items listed on the packing slip are present and in good condition.

If damage is evident, make a claim with the carrier and contact Fluke immediately. If items are missing, contact Fluke. See How to Contact Fluke.

Operation

The following sections describe the operation of the Survey Meter.

Warning

To prevent possible electrical shock, fire, or personal injury:

Do not put metal objects into connectors.

Fluke recommends that you wait for a one-minute warm-up period before you make a measurement. If the Survey Meter experiences a very large temperature change (for example, it moves indoors from outside) a longer warm-up period can be necessary to measure a value less than 50 μR/h.

External Controls

There are two external controls on the Survey Meter: and ON/OFF button and a MODE button.

ON/OFF Button

Press the ON/OFF button to turn on the Survey Meter. All the elements in the display turn on and the microprocessor runs through an initialization procedure. Part of the procedure includes reading the calibration coefficients stored in EEPROM. If an EEPROM read error occurs, an error code (E1) displays at power-on and unity calibration coefficients are used.

The bar graph and digital display will show a reading that decreases as the Survey Meter stabilizes. The initial reading usually starts in the 5 R/h range and decreases through the lower ranges to a reading of less than 50 μR/h within 120 seconds. When the elements in the display turn off, with the exception of those necessary for normal operation, the user can begin the measurement process.

Note

Background fluctuations may occur (less than 50 μR/h) returning to original reading typically in less than 3 seconds.

MODE Button

To configure the MODE button to the opposite function without a RS-232 connection, use the following procedure:

1. Turn off the Survey Meter.
2. Press the MODE button.
3. Turn on the Survey Meter while continuing to press the MODE button.
4. Release the MODE button when the display is in the “all elements on” condition.
5. Use the MODE button to toggle the Survey Meter between the Rate mode and the newly selected Freeze or Integrate mode.

Freeze Mode

When configured to select the Freeze mode, the MODE button acts as a toggle switch. Press the button until FREEZE appears on the display. Operation in the Freeze mode gives the user a constant reference of the highest exposure rate obtained from the time the freeze function is initialized. The highest reading appears as a single bar on the bar graph. The current reading continues to display on the digital display and the bar graph. If a measurement is obtained which exceeds the freeze bar reading, the freeze bar moves to the higher measurement point. The operating range of the Survey Meter remains locked on the highest range attained during the Freeze mode so that the scale and the multiplier remain the same.

For example, assume the scale units appear as 10, 20, 30, 40, 50, and the freeze bar is at 47 mR/h on the bar graph. If the Survey Meter then measures a radiation field of 120 mR/h, the scale units will change to 100, 200, 300, 400, 500 and the freeze bar appears on the graph at 120 mR/h. If the Survey Meter measurement goes below 100 mR/h, the units on the scale will not change until the Survey Meter is taken out of the Freeze mode. However, the digital display continues to show the current reading. The Survey Meter operates in the Freeze mode until the user toggles the MODE button to return to the normal operating mode.

Integrate Mode

The Integrate mode is operational 30 seconds after the Survey Meter is turned on and all of the time after that. However, the integrated exposure displays only when the MODE button has been configured as a toggle to display exposure rate/integrated exposure. If the MODE button is pressed within the 30 second initialization period of the Survey Meter, the display will read “0”.

When integration starts, “0.0 μR” displays. Toggle MODE to read exposure rate as required.

To reset the integration display, toggle the display from the Rate mode to the Integrate mode. Keep the MODE button pressed for approximately 5 seconds. The display will clear, and then read “0.0 μR.” Exposures are accumulated up to 99 R.

Self Test

When the Survey Meter is first turned on, it runs through a functional self-test procedure. During this self-test, the firmware version of the Survey Meter is displayed.

Warning

For safe operation and maintenance of the product, note the chamber bias from the self-test. If chamber bias is LO, the Product cannot measure high radiation rates accurately. The Product requires service, contact Fluke.

If the Survey Meter passes the self-test, it goes into the normal operating mode. If the Survey Meter fails the self-test, it remains locked with the firmware revision displayed. Contact Fluke for corrective action. See the How to Contact Fluke section.

Installation

The Survey Meter periodically tests for input at its RS-232 port. When an RS-232 signal is detected, the Survey Meter sends test signals using its sending device and, if RS-232 is present and operational, the Survey Meter enters into the communications mode. The Survey Meter display clears and the letters "CO" display as an indication that the Survey Meter is in the communications mode.

The Survey Meter is compatible with a CRT or printing terminal that has a standard RS-232 connector and a 1200-baud rate. A computer with a modem or terminal emulator can be used in place of the terminal. Set up the terminal or computer for a 1200 baud, 7 data bits, no parity bit, and 1 stop bits. To establish communications:

1. Attach the RS-232 cable assembly to the back of the Survey Meter.
2. When "CO" appears on the Survey Meter display, press the computer or terminal spacebar.
3. If the Survey Meter displays the "CO" message, but there is no response at the terminal press the spacebar twice.

If there is a problem getting the communications message (CO) to be displayed on the Survey Meter:

1. Be sure the computer communication port is active. The Survey Meter communication transmitter/RCR pair is active when it detects a negative mark voltage at the receiver input. (CO) then appears on the Survey Meter display.
2. Press space bar twice.

If there is still a problem, contact Fluke for further instructions. See the How to Contact Fluke section in this manual.

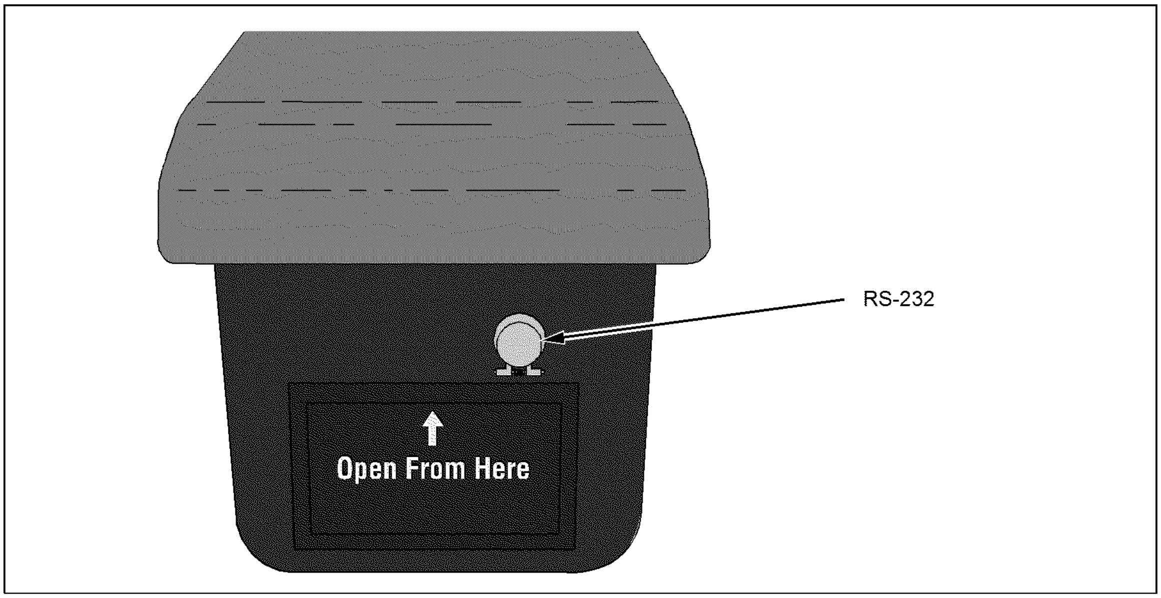


Figure 5. Location of RS-232 port

Operational check

Fluke recommends an operational check upon receipt of the Survey Meter and before each use. Monitor the start sequence. These results indicate the device is operating correctly:

- There are no error messages in the startup sequence.
- The display does not freeze (showing only the firmware number).
- The Survey Meter gets to the background level within 2 minutes.

Optional Check Source Use

For more testing use the check source (Fluke part number: 3463380).

To check the device, do the following:

1. Turn on and initialize Survey Meter.
2. After the self-test completes, wait for 1 minute.
3. Place check source on the white dot on the right hand side of the case.
4. Hold source in position until reading stabilizes and then record the reading.

This is your baseline measurement. Perform all subsequent operational checks in the same manner with the source in the same position. Each subsequent check source measurement should be within 30 % of the recorded baseline measurement.

Theory of Operation

Caution

To prevent damage to the Product, do not open or disassemble the Product. The ionization chamber is pressurized and sealed at the factory, because the high impedance circuits of the ion chamber are easily contaminated with grease and dirt that produce electrical leakage. The ion chamber cannot be disassembled for servicing.

The Survey Meter is a pressurized ionization chamber meter calibrated in exposure rate units of roentgens/hour (or Sieverts/hour) for gamma and x-radiation in the energy range of 20 keV to 2 MeV. The Survey Meter responds to, but is not calibrated for beta radiation. Beta energies that can be measured are above 1 MeV.

The liquid crystal, supertwist display shows the radiation rate in digital and analog form with the range multiplier values also showing on the scale. It is a lightweight electronic device that requires the computational capabilities of a microprocessor to make it operate. It functions in a multiplex mode called quadriplex. This mode uses four back-planes to accommodate the 128 elements of the display.

The microprocessor performs data collection, averaging, and multiplication by stored calibration factors, range changing, and battery check functions, in addition to driving the LCD. Between computational periods, it "sleeps" in a low power mode to conserve battery power. The microprocessor reads stored information from an electrically erasable memory, EEPROM, which is used by the program for calibration and display units. The EEPROM will retain stored data when the Survey Meter is OFF or when the batteries are removed. Data can be entered into the EEPROM using the RS-232 port.

Collection voltage for the ion chamber is approximately 105 V obtained from five lithium cells. All internal power for the Survey Meter is supplied by the 9 volt batteries.

The digital and bar graph displays read directly. The bar graph display update periods are listed in Table . The digital display updates at 1 second intervals nearest the current bar display update. The bar graph and digits display do not always show the same reading because the bar graph is faster than the digital update. It is more convenient to watch the bar graph when the reading is changing quickly and to read the value of a slowly changing or static reading by looking at the digital display.

The bar graph display is a digital presentation, programmed to appear as a linear analog meter display. It is also referred to as the analog display throughout this manual.

Table 2. Bar Graph Display Update Periods

Range	Update Period
5 R/h (50 mSv/h)	0.05 second
500 mR/h (5 mSv/h)	0.05 second
50 mR/h (500 µSv/h)	0.05 second
5 mR/h (50 µSv/h)	0.05 second
500 µR/h (5 µSv/h)	0.15 second

There are 20 bars between each major division. The numerical values of the five major divisions change appropriately for the range in which the Survey Meter is operating. For instance, the first major division would have the numeric value of 1, 10 or 100. The minor divisions are worth 0.05, 0.5 or 5. The incremental nature of both the digital reading and the analog bar graph provide greater accuracy for reading in different portions of the scale. For example, on the 0 mR/h to 5 mR/h range, with a digital reading of 2.0 and above, the analog bar graph can be read more accurately than the digital display. Below a digital reading of 2.0, the digital display is more accurate because it consists of three significant digits. The stated precision of the digital display is accurate only above a reading of 5 % of the full scale.

Note

The same analysis applies to all the other ranges because the number of significant digits or active bar elements are independent of the position of the decimal point or the unit's multiplier.

There is a small hysteresis built into the range changing circuit so that the Survey Meter does not keep changing scales if the reading is at the threshold of range change. It is important in calibration of the Survey Meter that the calibration coefficients track from range to range because an oscillatory condition can occur if the calibration on a given range is low and the coefficient for the next more sensitive range is high.

The program in the Survey Meter ROM is proprietary to Fluke. The firmware version appears in the digital part of the LCD display (prior to the "all elements on" display) when the Survey Meter is turned on. The firmware program consists of three main parts: operation, communication, and monitoring.

The operation portion of the firmware performs all of the control functions needed to read and control the electrometer and range change amplifier, calculate radiation rate, and display the calculated values on the LCD Display. In addition, the measured data are smoothed and displayed in an exponential manner with time that simulates the rise and fall time of an ordinary meter display. Range changing is performed automatically. If a large increase in signal is detected, the range changing skips to higher ranges bypassing exponential rise with time to get to the new reading quickly. The Survey Meter continually integrates the detected radiation signal and saves the accumulated amount that may be read by the operator at any time. The operator may also reset the integration process.

When the RS-232 cable is attached to the Survey Meter, the Survey Meter detects its presence and runs the communications portion of the program. The communication parameters are 1200, N, 7, and 1. Serial communications are performed in software rather than using a hardware device. The operation program can be run from communications in the Test mode.

Maintenance

Very little maintenance is required for the Survey Meter, but some periodic attention may be necessary, especially if the Survey Meter is used in harsh industrial conditions.

Warning

To prevent possible electrical shock, fire, or personal injury:

Do not operate the Product with covers removed or the case open. Hazardous voltage exposure is possible.

Use only specified replacement parts.

Have an approved technician repair the Product.

Only assemble and operate high-pressure systems if you know the correct safety procedures. High-pressure liquids and gases are hazardous and the energy from them can be released without warning.

Many components on the printed circuit board are static sensitive. Obey all ESD precautions when you touch the printed circuit board assembly.

Routine Cleaning

Do not immerse the Survey Meter. The Survey Meter is not waterproof; liquid could damage the circuits. The Survey Meter should be kept clean and free from dirt and contamination. To clean the Survey Meter, wipe with a damp cloth using any commercially available cleaning or decontaminating agent.

Storage

Storage of Fluke Biomedical instruments must comply with Level B storage requirements as outlined in ANSI N45.2.2 (1972), Section 6.1.2 (.2). The storage area shall comply with ANSI N45.2.2 (1972), Section 6.2 Storage Area, paragraphs 6.2.1 through 6.2.5. Housekeeping shall conform to ANSI N45.2.3 (1972).

Level B components must be stored within a fire resistant, tear resistant, weather tight enclosure, in a well-ventilated building or equivalent.

Storage of Fluke Biomedical instruments must comply with the following considerations:

1. Inspection and examination of items in storage must be in accordance with ANSI N45.2.2 (1972), Section 6.4.1.
2. Requirements for proper storage must be documented and written procedures, or instructions shall be established.
3. In the event of a fire, post-fire evaluation must be in accordance with ANSI N45.2.2 (1972), Section 6.4.3.
4. Removal of items from storage must be in accordance with ANSI N45.2.2 (1972), Sections 6.5 and 6.6.

Battery Replacement

Warning

To prevent possible electrical shock, fire, or personal injury:

Batteries contain hazardous chemicals that can cause burns or explode. If exposure to chemicals occurs, clean with water and get medical aid.

Do not disassemble the battery.

Repair the Product before use if the battery leaks.

Be sure that the battery polarity is correct to prevent battery leakage.

Do not short the battery terminals together.

Do not disassemble or crush battery cells and battery packs.

Do not keep cells or batteries in a container where the terminals can be shorted.

Do not put battery cells and battery packs near heat or fire. Do not put in sunlight.

Do not operate the Product with covers removed or the case open. Hazardous voltage exposure is possible.

This Product contains lithium cells with a potential voltage of 105 V on the battery assembly. To prevent personal injury or damage to the Product, be careful with this assembly during removal and installation.

The LOW BAT message will appear on the display approximately 6 hours prior to the Survey Meter becoming inoperable. To ensure that the Survey Meter operates to specification, change the batteries within 4 hours after the LOW BAT message appears. The Survey Meter will function on one battery for approximately 100 hours, allowing replacement of one battery at a time if the Survey Meter must remain operational during battery changeover. Use regular or alkaline batteries for replacement purposes.

Both 9 volt batteries are located in the rear of the Survey Meter and are easily accessible and replaceable with the battery cover removed.

hms02.eps

Figure 6. Battery Access

Replaceable Parts Information

Fluke maintains a complete inventory of all normal replaceable parts. To place an order, or to obtain information concerning replaceable parts, contact Fluke. See the How to Contact Fluke section in this manual.

Table 3. Replaceable Parts List

Part Number	Description
3567752	Keypad Overlay, Red
3567765	Handle, Yellow
3567776	Handle, Foam Grip, Black
3463380	Check source, CS-137, 10 UCI, Flat disc, 1-inch diameter
614487	Battery, 9 V, Alkaline

Recalibration and Service Information

Fluke recommends a once yearly calibration on your Survey Meter. If your Survey Meter needs recalibration or repair, we request that you contact Fluke. See the How to Contact Fluke section in this manual.

More information concerning the operation, application, or service of your Survey Meter can be obtained from the applications engineer at the numbers listed above.

Troubleshooting

Caution

For safe operation and maintenance of the Product, use caution when working on this Product. If the device indicates a relatively high radiation rate, there is a possibility that the Product has been contaminated. High rates can quickly cause the operator's cumulative exposure to increase with the potential for injury.

Note

Install fresh batteries prior to performing any calibration on the Survey Meter.

If the Survey Meter fails self-test, it will remain locked on the firmware revision number. See the How to Contact Fluke section.

ATTACHMENT D

Durridge RAD7 Radon Detector User Manual

RAD7 RADON DETECTOR

User Manual

Owner__________________________

Serial #______________

SERVICE RECORD

Date	Service

It is recommended that the unit be returned to DURRIDGE Company annually, for recalibration.

DURRIDGE Company Inc.
524 Boston Rd
Billerica, MA 01821
Tel: (978)-667-9556
Fax: (978)-667-9557
service@durridge.com
www.durridge.com

WARNING

Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened. Due to battery power, the instrument may still be dangerous.

Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

TABLE OF CONTENTS

INTRODUCTION

The RAD7 is a highly versatile instrument that can form the basis of a comprehensive radon measurement system. It may be used in many different modes for different purposes. This manual adopts a progressive approach, in which there is, first, a simple, step-by-step description of how to get readings for a) real-time monitoring, and b) sniffing. Next comes a more detailed description of the many features of the instrument and how to access them. The rest of the manual covers a whole range of topics, in somewhat arbitrary order. We recommend that, as soon as possible, you read the entire text, just so that you will have an idea of what there is. While you can start to make good measurements on the first day of ownership of the RAD7, it can take years to master the subtleties of radon and thoron behavior, and to appreciate the full capabilities of the instrument.

We have tried to make the manual easy to use, with a useful table of contents. Please let us know how well we have succeeded. If there are some topics inadequately covered, please tell us. We wll issue updates from time to time.

Points of special note

The RAD7 is a rugged and long-lasting piece of equipment. There are many units still in daily use that were sold ten years ago or more. However, it is a sophisticated, precision electronic device, and itis not hermetically sealed, so please treat it with respect. Please do not allow water, oher liquids or dirt to get into the machine. If using it somewhere where it may get splashed, damaged, or exposed to rain, please protect it. See Chapter 4.7.1.

The batteries are lead-acid technology, like a car's. If left in a discharged state they wll lose capacity. After running the RAD7 on its batteries please recharge them as soon as possible (by plugging in the unit). With careful use the batteries will last five years or more.

Finally, there is one security feature that is sometimes inadvertently set by an inexperienced, though authorized, user; namely the key pad lockout. If the key pad ceases to function, and all you see is DURRIDGE RAD7 on the display, just do the following: Hold down the [ENTER] and two arrow keys until you hear a beep, release the three keys and immediately push [MENU]. You should then be rewarded by >Test on the display. If the tone was set toOFF, then you will not hear the beep, so hold the three keys down for three to four seconds, before releasing them and pushing[MENU], - try hold-down times a little longer, or shorter, if, at first, you do not succeed.

DURRIDGE Company Inc.
524 Boston Rd, Billerica, MA 01821 USA
Tel: (978)-667-9556 Fax: (978)-667-9557
Email: Service@durridge.com
Web: www.durridge.com

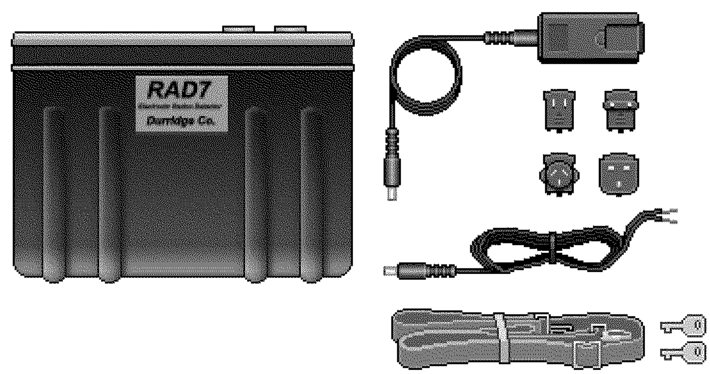
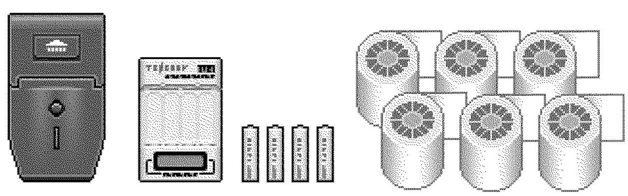
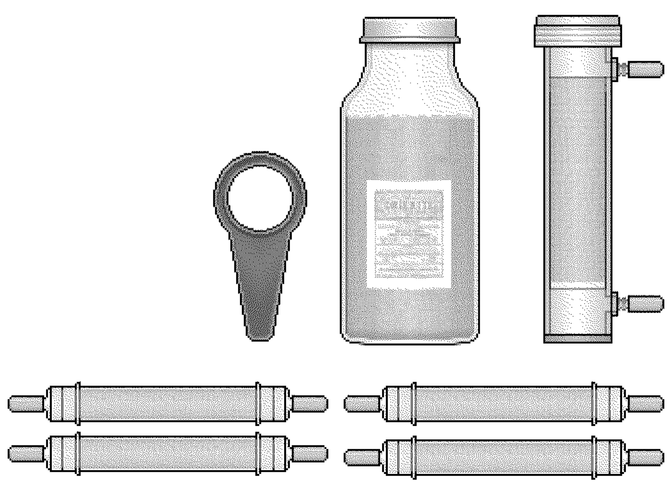
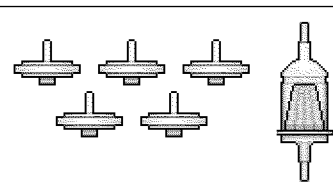
European Representative:
Dr. Martyn J. Key
c/o Radiansa Consulting S.L.
Montcalm 20-22, 17006 Girona, Spain
Tel: +34 972 243232

1. GETTING STARTED:
YOUR FIRST DAY WITH THE*RAD7*

1.1 Unpacking

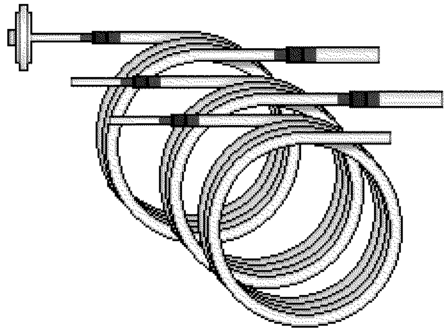
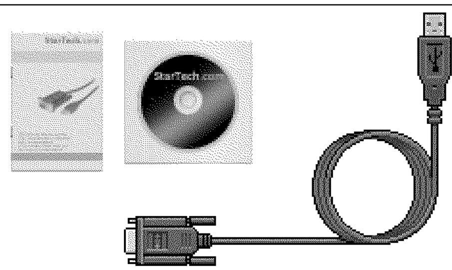
First make sure you have everything you are supposed to have. Take the materials out of the packing boxes and see if you have all the items shown in the diagram below, or on the packing list enclosed with the shipment. If anything is missing, please email DURRIDGE immediately or call us at (978) 667-9556.

RAD7 Packing List

	**RAD7 and Case Accessories** •RAD7 electronic radon detector •12V adaptor w/ 4 plugs • 12V cord for custom applications •RAD7 Carrying Strap •Keys for RAD7 case
	**RAD7 Printer Supplies** •Newhandy infrared printer •Battery Charger •4 Rechargeable AA batteries •6 Rolls printer paper
	**Drying Tubes and Desiccant** •Gas drying unit •Opener tool for drying unit •5 lbs desiccant •4 drying tubes
	**RAD7 Filters** •5 RAD7 inlet filters •1 Dust filter

(Continued on next page.)

RAD7 Packing List (Continued)

	**Vinyl Tubing Set (3ft x 3)** •From sample to drying tube •From drying tube to RAD7 inlet •From RAD7 outlet to exhaust
	**USB/Serial Supplies** •Null modem cable •USB Cable •USB to serial adaptor
	**RAD7 Documentation Binder** •RAD7 User's Manual •Infrared Printer Manual •Additional documentation •DURRIDGE Software CD •DURRIDGE Software USB Stick

1.2 General Safety Instructions

For your own safety and the proper operation of RAD7:

DO NOT spill liquids onto the machine.
DO NOT expose operating panel of machine to rain or any other excess moisture.
DO NOT allow liquid to be sucked into inlet tube.

If you intend to use the instrument in a harsh environment, give it some protection. Even just a transparent plastic bag enclosing the RAD7 (but not the air sampling tube) can protect it from splashing mud and water. Allowing the dry air from the RAD7 outlet to exhaust into the interior of the bag will keep the RAD7 in a clean and dry environment.

If liquid does get into the machine, please disconnect the power cord, turn off the power switch, and follow the instructions in Chapter 4.7.1, Harsh and Hazardous Environments: Splashing Water. It will be necessary to return the RAD7 to DURRIDGE for repair.

Do not use your RAD7 if the instrument is damaged or malfunctioning. Please call, or email, the DURRIDGE service department, who will advise what to do about the problem.

Replace a frayed or damaged power cord immediately. Electrical equipment may be hazardous if misused. Keep away from children.

Do not open or attempt to repair the machine. The detector has an internal high voltage supply that can generate more than 2,500V.

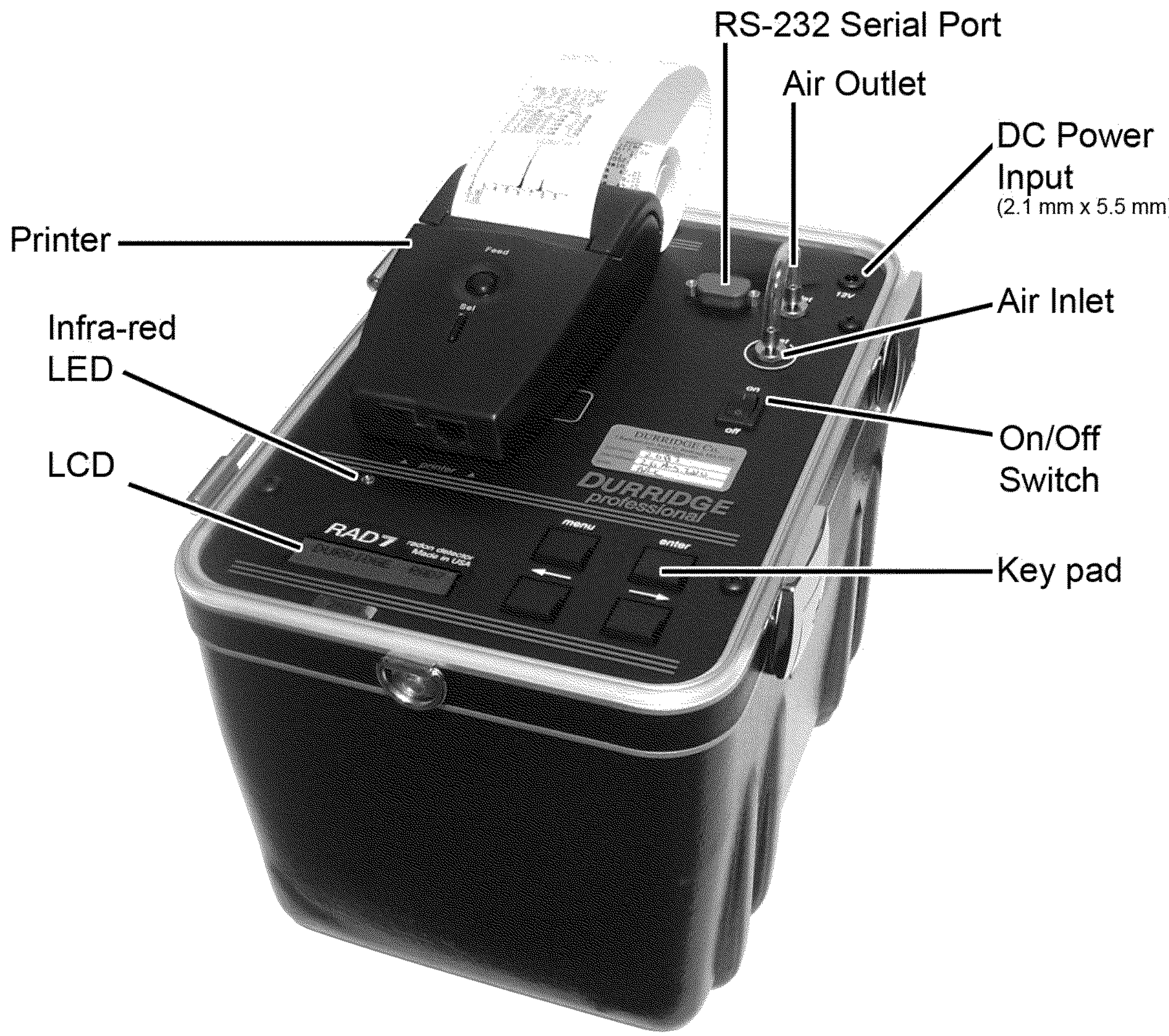
The batteries are Gates Monobloc type 0819-0012, 6V 2.5Ah. There are two installed in the instrument. They are not user replaceable.

1.2.1 Air Travel

The RAD7 is safe to take on an airplane either as carry-on or checked baggage. It is probably easiest, and least likely to cause problems, if it is put inside a suitcase, with clothes, and checked in.

Some airlines and some airline staff are concerned about lead-technology batteries, such as those in the RAD7. An MSDS sheet, issued by the battery manufacturer, is enclosed with the manual in the RAD7 documentation. A copy of that should be carried and presented when requested, when traveling with a RAD7 by air.

1.3 Taking a Look



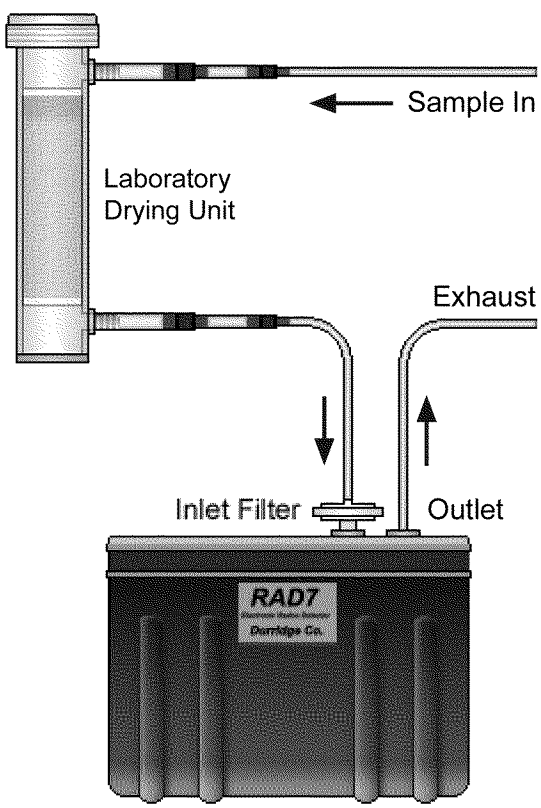
The RAD7 Professional Electronic Radon Detector

1.4 Starting a Two-day Test

You will need the RAD7 and power cord, the Laboratory Drying Unit (the large tube of desiccant, with a screw cap at one end), an inlet filter (one of the six small filters supplied), the piece of tubing with a 5/16" ID segment at one end and a $\frac{1}{8}$" ID segment at the other and the printer.

On first starting up, you may need to set the clock for your time zone (See Setup Clock, Chapter 2.4.11). Switch on the RAD7, push [MENU], then push [➔] twice. You will see Setup on the display. Push [ENTER], then push [➔] ten times. You will see Setup Clock. Push [ENTER]. Use the arrow keys to adjust hours, minutes, seconds, day, month and year, pushing [ENTER] to confirm each setting. Now we are ready to continue.

RAD7 Normal Configuration



DURRIDGE RAD7
Radon Monitor

a) Attach the filter to the tubing (push it into the end with the insert).

b) Carefully remove both plastic caps from the Drying Unit (you will need them later, to reseal the unit). Attach the sleeved end of the tubing to the tube fitting, on the Drying Unit, farthest from the screw cap.

c) Attach the filter to the Inlet port of the RAD7. The air sampling system is now set up for the measurement. (See RAD7 Standard Configuration diagram at left.)

d) Plug in the RAD7 and switch on.

e) Push [MENU], [ENTER], then push [➔] four times. You should see on the LCD display: Test Purge.

f) Push [ENTER]. The pump should start.

g) Set up the printer (insert paper and batteries - see manual).

h) Place printer between green lines on face plate (See photo, Chapter 1.3).

i) After purging for some time (normally, at least five minutes), push [MENU], and [➔] two times, you will see: Setup on the display.

j) Push [ENTER] twice, then push either arrow key repeatedly until you see:
Protocol: 2-Day on the display. Push [ENTER].

k) With Setup on the display, push [ENTER], then [➔] seven times, to see >Setup Format on the display. Push [ENTER] then use arrow keys to select Format: Short. Push [ENTER].

l) Switch off the RAD7. Switch on the printer, now switch the RAD7 back on. The printer will print out something like the following:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 21-MAY-13

Last used
```

```
!   FRI  21-MAY-13!  17:30

Current  settings
!   FRI  21-MAY-13!  19:09

Protocol:  2-Day
Cycle:  01:00
Recycle:  48
Mode:  Auto
Thoron:  Off
Pump:  Auto
Tone:  Geiger
Format:  Short
Units:  pCi/L    C
```

m) Push [MENU], [ENTER], [➔]. You should see on the LCD display: >Test Start

n) Push [ENTER]. The pump will start running. On the LCD display you will see something like:

```
0101! !      Live!  !   Sniff
00:59:37!    !      !   00001
```

You are now monitoring the radon level right where you are. Every hour, the printer will print out a reading something like this:

```
0102    2.69   " 0.73   p    Sniff
!   FRI   21-MAY-13      19:41
!   26.8 C    RH:  7%    B:7.06V
```

Where 0102 are the run (01) and cycle (02) numbers, 2.69 is the measured radon concentration, 0.73 is the two-sigma STATISTICAL uncertainty, p indicates the units (in this case pCi/L), and Sniff shows that, for this reading, only the Po-218 decays are being counted (after three hours, the mode changes automatically to Normal). The second line is clearly the date and time, while the third shows the temperature and humidity inside the measurement chamber, and the battery voltage. Medium and Long format settings print more information each cycle.

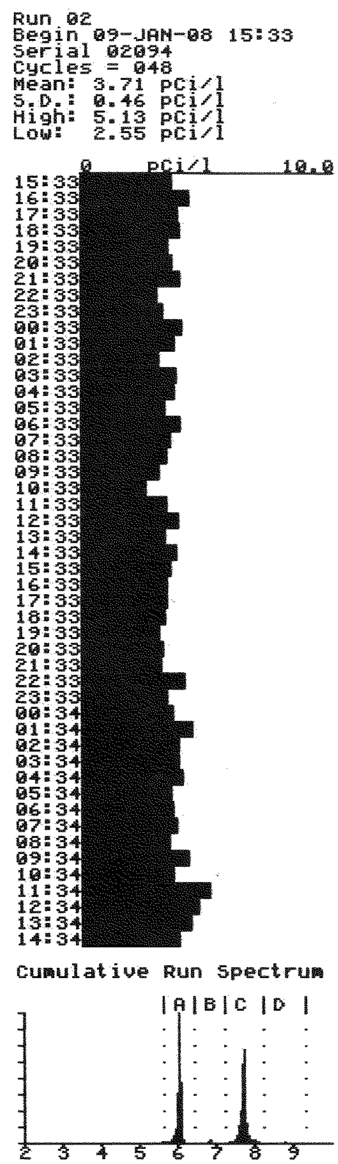
If you allow the RAD7 to complete a run, it will print out a summary of the entire run, including:

1. Date and time
2. Machine serial number
3. Average value for the test
4. Bar chart of the individual readings, and
5. Cumulative alpha energy spectrum.

In the example shown it may be seen that the average level was 3.71 pCi/L, or 137 Bq/m^3.

To terminate the run early, you may switch off the RAD7. The data collected, to the end of the last completed cycle, is automatically stored in the RAD7 memory, and available for later display, printing or download to a PC. If you wish to store the last, incomplete cycle data as well, use Test Save before switching off the RAD7. When you do this, the end-of-run printout does not take place. The summary is stored in memory and may be printed at any time, except that the cumulative spectrum, which would have been printed out at the end of the run, is lost.

End-of-Run Printout



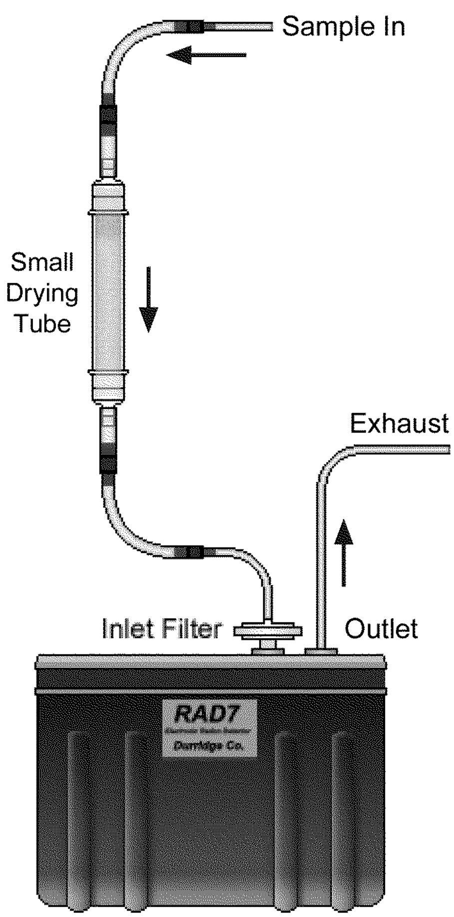
1.5 Starting a Sniff Test

Sniffing lets you make quick, qualitative surveys of radon and thoron levels. It may be used to search for radon entry points. There are some advantages in sniffing for both thoron and radon at the same time, (see Chapter 3.13.3), so that is the procedure described here.

You will need the same equipment as for the 2-day test, above, except that a small drying tube should be used, instead of the laboratory drying unit. Also, for portability, you may remove the external power from the RAD7, and run the RAD7 on its batteries.

If you have not already done so, set the clock, as described above.

RAD7 SNIFF Configuration



DURRIDGE RAD7
Radon Monitor

a) Attach the filter to the tubing (push it into the end with the ⅛" ID segment)

b) Carefully remove both plastic caps from the small drying tube (you will need them later, to reseal the unit). Attach the 5/16" ID end of the tubing to one end of the tube.

c) Attach the filter to the Inlet port of the RAD7. Make sure it is firmly fit onto the inlet. The air sampling system is now set up for the measurement. While testing, you can use the small drying tube as a wand, to collect your air sample from the location of interest.

d) Plug in the RAD7 and switch on.

e) Push [MENU], [ENTER], then push [➔] four times. You should see on the LCD display: Test Purge.

f) Push [ENTER]. The pump should start.

g) Set up the printer.

h) Place printer between green lines on the face plate (See photo, Chapter 1.3).

i) After purging for a few minutes push [MENU], and [➔] two times, you will see: >Setup on the display.

j) Push [ENTER] twice, then push either arrow key repeatedly until you see: Protocol: Thoron on the display. Push [ENTER]. (See Chapter 2.4.5 for difference between Thoron and Sniff protocols).

k) With Setup on the display, push [ENTER], then [➔] seven times, to see Setup Format on the display. Push [ENTER] then use arrow keys to select Format: Short. Push [ENTER].

l) Switch off the RAD7. Switch on the printer, now switch the RAD7 back on. The printer will print out something like the following:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 21-MAY-08

Last used
! WED 23-MAY-08! 17:30

Current settings
! FRI 25-MAY-08! 19:09

Protocol: Thoron
Cycle: 00:05
Recycle: 00
Mode: Sniff
Thoron: On
Pump: Auto
Tone: Geiger
Format: Short
Units: pCi/L   C
!
```

m) Push [MENU], [ENTER], [➔]. You should see on the LCD display: >Test Start

n) Push [ENTER]. The pump will start running. On the LCD display you will see something like:

```
0201! !      Live! !   Sniff
00:04:37!    !     !   00001
```

You are now sniffing for thoron and radon. Every five minutes, the printer will print out a reading something like this:

```
0203! 2.69  " 2.83!  p  Sniff
!  !  1.68  " 2.15!  p  Thoron
!  FRI  21-MAY-99      9:41
!  26.8 °C   RH: 7%   B:7.06V
```

Where 0203 are the run (02) and cycle (03) numbers, 2.69 is the measured radon concentration, 2.83 is the two-sigma STATISTICAL uncertainty, p indicates the units (in this case pCi/L), and Sniff shows that, for this reading, only the Po-218 decays are being counted. The second line is the measured thoron concentration and uncertainty. The third line is now the date and time, while the fourth shows the temperature and humidity inside the measurement chamber, and the battery voltage. Medium and Long format settings print more information each cycle.

Note that the Po-218 has a 3-minute half life. After moving to a new location, it will take about 15 minutes for the count rate to reach equilibrium with the new radon concentration. So not until after the third 5-minute cycle will the reading indicate the new level. However, the thoron daughter, Po-216, has a very short half life (150 ms), so the response of the RAD7 to thoron is virtually instantaneous. For thoron, the first 5-minute cycle is as good as any other.
Thoron will only be found very close to radon entry points. That, together with its fast response, makes thoron sniffing an excellent sleuth for radon entry points.

To terminate the run any time, you may switch off the RAD7. The data collected, of completed cycles, is stored in the RAD7 memory, and available for later display, printing or downloading to a PC.

2. BASICS OF *RAD7* OPERATION

2.1 Introduction

2.1.1 The Key Pad

The RAD7 is operated through a four-key menu-driven interface. These four keys allow you to look at the commands, select one, and then do it.

Menu Key

Press [MENU] and you see the menu prompt (>) and the word Test:

```
>Test
```

Arrow Keys

Press the forward and backward arrow keys to go through the available options. To advance quickly through the options, hold down the key so that it "auto-repeats."

The arrow keys allow you to move right and left through the various commands, looking for the action you want.

Enter Key

When you have decided on a certain menu option, you select it by pressing [ENTER]. The enter key tells the RAD7 that you have made your selection. You are telling it what you want it to do.

The enter key makes it happen.

2.1.2 Command List

The RAD7 command list has four command groups: Test, Data, Setup and Special. The Test group of commands controls the collection of new radon data. The Data group retrieves data from memory, outputs them, and gets rid of old, unwanted data. The Setup group prepares the RAD7 to operate according to your requirements. The Special group is a set of commands that are available when RADLINK, the remote control software, is loaded.

2.2 Test

The Test group of commands controls the collection of radon data and allows you to manipulate the current test (test-in-progress). You can start and stop data collection, save or clear the current test, or print the current test as it stands. (The Test commands do not allow access to stored data. You have to go to Data for that.)

2.2.1 Test Status

To see the status display, enter the Test Status command. Press [MENU], [ENTER], [ENTER]

On the LCD display, you will see:

```
0501! !     Idle! !  Sniff
00:30:00!   !     !  00000
```

On the upper left, you see the current run number/ cycle number (0501 - run 05, cycle 01.).

The middle shows the detector status (Idle or Live), and the upper right gives the current test mode (Sniff, Normal or Grab). (Note that in AUTO mode, the indication will change from Sniff to Normal after three hours of measurement.

Lower left shows the count-down timer (00:30:00 = 30 minutes) which counts down to zero when the detector is Live (i.e., a test is in progress). The lower right shows the total number of counts since the beginning of the current cycle.

The arrow keys may now be used to access additional status information.

Press [➔] once, and you will see something like this:

```
Last reading:
0409! 1.80 " 0.74!p
```

The lower left is the run number (2 digits) and cycle number (2 digits) of the last completed cycle stored to memory.

The lower right is the radon reading and two-sigma statistical uncertainty, followed by "p", indicating picoCuries/liter, or "b" for Becquerels/ cubic meter.

When a cycle ends, the information on this display is updated. If there have been no readings yet, the display will show

```
No readings yet.
```

Press [➔] once again, and now you will see something like this:

```
24.8°C!      RH:3%
B: 6.36V!    P:  00mA
```

Top left is the internal temperature. (To change from Celsius to Fahrenheit, see Chapter 2.4.9, Setup Units.)

Top right shows the internal Relative Humidity reading. When testing, maintain this value at 10% or less, by using the desiccant.

Bottom left is the battery voltage. This should range from about 6.00V to 7.10V. A discharged battery (less than 6.00) should be recharged as soon as possible. A fully charged battery will rest at 6.40 to 6.50 V. During a recharge, the voltage will eventually rise above 7.00 V. At no time should this read higher than 7.20V. In the lower right is the pump current. This number should vary from 00mA (pump off) to 80mA. When the pump is running with a light load, the current will range from 40-70mA. When the pump is running with a heavy load (clogged filter or blocked hose), the current will go to 90mA or higher. Pump currents above 90mA are considered a sign of trouble. Try changing the filters and check for blockage.

Press [➔] again, and you will see something like this:

```
HV:  2218V,  10%
L:   02        S:  0.21V
```

This is a display of diagnostic values. Ordinarily it will be of little interest to you.

The top line is the high voltage reading and duty cycle. The range of normal values is from 2000 to 2500V, and from 8% to 18%.

The lower left corner is the leakage current. At room temperature, this value will normally range from 0 to 10. Higher temperatures ordinarily cause this value to rise. Excessive leakage current will result in "noise" in the lower energy end of the spectrum, and will also cause broadening of the alpha peaks.

The lower right corner is the signal voltage from the analog circuit. This number should be "stable"; that is, fluctuations should be no more than " 0.05V from the average value.

Press [➔] yet again, and you will see something like this:

```
w! |  cpm!  | +/- !  |  %tot
A! |  6.0!  |  4.3!  |  48.8
```

This is the display for the A window data. You may press [➔] to advance to B, C, D, etc.

The RAD7 records 8 windows (A - H) every time you make a measurement. They separate counts due to daughters of radon and thoron, and the background. Specific alpha particles end up in specific windows.

W: The window letter.
cpm: The counts per minute observed in the window.
+/-: The two-sigma statistical uncertainty of the cpm value, also in units of cpm.
%tot: The number of counts in the window as a percentage of the total counts in the spectrum. This tells you quickly where the majority of the counts are: In the 3-minute radon peak (window A), or the long-lived radon peak (window C), etc.

As always, you press the [MENU] key to exit this display and return to the start of the menu.

2.2.1a Quick Save-and-Restart

This function allows the user to end a sniff test, store it to memory, and start up a new sniff test, all using a single key. It operates only from the SNIFF mode.

From the status display (showing the countdown timer), press the [ENTER] key once. The display will show:

```
Save and restart
```

? Yes

Press the [ENTER] key once more to confirm your intention. To escape, push the [MENU] key or push an arrow key to select "No" and push [ENTER].

2.2.2 Test Start and Test Stop

To start testing (or "counting"), after you have chosen the required setup, go to >Test Start by pressing [MENU], [ENTER], [➔], and then [ENTER]. The display will indicate that counting has begun:

Start counting.

One second later, the Status display will appear with the countdown timer in motion:

```
0501! !      Live! !  Sniff
00:29:37 ! !       !  00001
```

When the countdown reaches zero, the RAD7 will automatically calculate the radon concentration, store (or "save") the counts to memory, and clear the counters to begin a new cycle.

To interrupt the measurement, go to>Test Stop by pressing [MENU], [ENTER], [➔], [ENTER].

The display will respond:

Stop counting.

After one second, the display will go back to the top of the menu >Test.

You may wish to examine the Status display to verify that the status is Idle.

To resume testing from exactly the same point in the cycle where you stopped, select >Test Start as described above.

Note that Stop does not terminate the run, it is a pause. If you do not wish to resume testing from the same point, you should select either >Test Save or >Test Clear before continuing. This will terminate the suspended test, store it to memory (Save) or wipe it out (Clear), and clear the counters to begin a new run.

2.2.3 Test Save

The >Test Save command suspends counting and saves the suspended test (test-in-progress) to memory as if it had reached completion. Test Save completes the current run, so any subsequent test data will be stored as a new run. The display momentarily shows the run and cycle number in the form of 0101 Saved. This command may be accessed whether the status is Live or Idle. It always leaves the status Idle.

You will find this command especially useful when you wish to move the instrument to another location without waiting for the countdown to reach zero, but without losing that last incomplete cycle. The calculated radon concentration from the incomplete cycle is still good.

2.2.4 Test Clear

The >Test Clear command causes counting to be suspended and the current run to be completed without saving the last (suspended) incomplete cycle. Subsequent test data will be stored as a new run. You must answer Yes to the question Are you sure? in order to activate this command.

This command may be accessed whether the status is Live or Idle. It always leaves the status Idle.

2.2.5 Test Purge

The >Test Purge command suspends counting and begins purging the detector. The pump begins running and the high voltage circuit turns off in order to clear the sample chamber of radon gas and daughters as quickly as possible. You must provide clean, desiccated, radon-free air to the inlet in order to push out any radon that was previously sampled. Outdoor air is usually adequate for this purpose.

As always, use the inlet filter and drying tube. Ten minutes is usually sufficient for bringing the background down after exposure to moderate amounts of radon.

In order to dry out the RAD7 without using up much desiccant, connect the hoses from the RAD7 to the drying unit, as a loop. When the pump runs, the same air will circulate repeatedly through the desiccant. This procedure will efficiently remove residual moisture from the RAD7. This does not introduce any fresh air, and so does not change the radon level in the instrument, but you can make a measurement of the background while it is set up in this configuration.

To end the purge, answer Yes to the question Stop purge? which appears on the display. Alternatively, you may push [MENU] to end the purge.

2.2.6 Test Lock

If you push [ENTER] when this is displayed, it will lock the key pad. The LCD display will just show:

DURRIDGE RAD7

Nobody will be able to unlock the key pad, unless they know the secret.
If the key pad was locked during a measurement, then the readings will continue as normal, with the RAD7 recording all the data, until the end of the run.

Switching the unit off, while locked, will stop the measurement, but the key pad will still be locked when the RAD7 is switched on again.

To unlock the key pad, hold the [ENTER] and both arrow keys down, all together, for 3 - 4 seconds, or until the unit beeps, then release the three keys and push [MENU] immediately.

2.2.7 Test Sleep

The >Test Sleep command allows you to turn off most of the electronic circuits, with the power switch on, in order to conserve battery charge. A fully charged RAD7 should be able to "sleep" for about one week on batteries alone. Press the menu key to "wake up" the RAD7.

The Sleep function was for older models that did not have the Real Time Clock (RTC) and Non-Volatile Memory (NVRAM) options. New and upgraded instruments may be shut down completely, power switch off, without losing any stored data or clock.

2.2.8 Test Print

The >Test Print command calculates results for an incomplete or suspended test cycle and prints them according to the print format that is currently set.

Spectrum output is available by selecting >Setup Format Long beforehand.

If you wish to abort printing, press the [MENU] key. The run number and cycle number that ordinarily appear on printed data are replaced by 0000 to signify that the cycle is not completed.

2.2.9 Test Com

The >Test Com command outputs the results for an incomplete test cycle to the serial port.

If you wish to abort output, press the menu key. The run number and cycle number that ordinarily appear with the data are replaced by 0000 to signify that the cycle is not completed.

2.3 Data

The Data group of commands retrieves data from memory, displays it, prints it, reports it graphically, and outputs it to the serial port. The Data group also includes commands for managing memory. The memory will hold the data for 1,000 cycles, in up to 100 runs.

Many commands in the Data group require you to enter a two-digit run number after the command. The "default" run number (the one automatically set if you do nothing) is the run number of the last complete cycle of data stored. The arrow keys allow you to select any other run number.

2.3.1 Data Read

Select >Data Read followed by a two-digit run number, to examine radon readings from that particular run. For example, select >Data Read 01 to examine readings from run number 01, the first test in memory.

You will see something like this:

```
0101! 23.3 " 1.54!p
  11:45 !   19-MAY-99
```

Line 1 is the run/cycle number followed by the radon concentration, two-sigma uncertainty, and unit indicator. This example shows:

Run 01, Cycle 01, 23.3 " 1.54 pCi/L.

Line 2 is the time (24-hour military time) and date the reading was completed.

Press [➔] to advance to the next reading in memory; press the backward arrow to go back to the previous reading.

To quit examining data, press [ENTER] or [MENU].

Note that large numbers are presented in shorthand notation. The symbol "K" stands for 1,000 and "M" stands for 1,000,000. For example, 33K2 stands for 33,200.

2.3.2 Data Print

To print out a run of data from memory, select >Data Print followed by the two-digit run number. For example, to print the data from run number 05, select >Data Print 05.

If the printer format has been set to Short, the following printout will be made for each cycle of the run:

```
0501! 2.69  " 2.83!  p!       Sniff
!  FRI  21-MAY-99   19:41
!  26.8 EC   RH: 7%   B:7.06V
```

Line 1 is the run/cycle number, the radon concentration, the two-sigma uncertainty, the units indicator (p=picoCuries per liter, B=Becquerels per cubic meter), and the mode indicator.

Line 2 is the date and time that the cycle was completed and stored to memory.

Line 3 is the temperature (in either "C" Celsius or "F" Fahrenheit), relative humidity (internal), and battery voltage at the time the cycle ended.

If the printer format has been set to Medium or Long, then you will see a printout like this for each cycle:

```
0501! 2.69  " 2.83!  p!       Sniff
!  FRI  21-MAY-99   19:41
!  26.8 EC   RH: 7%   B:7.06V
Total Counts:!   42.
Livetime:!  27.8min
A:!0.53"0.08!     cpm!       47.3%
B:!0.02"0.02!     cpm!       1.7%
C:!0.52"0.08!     cpm!       46.4%
D:!0.01"0.02!     cpm!       0.9%
O:!0.04"0.03!     cpm!       3.6%
```

Lines 1, 2 and 3 are the same as in Short format, as outlined above. Line 4 is the total number of counts detected during the cycle.

Line 5 is the livetime, the time that the detector was actively collecting data.

Lines 6 through 10 are the windows data for windows A, B, C, D, and O. (O is the consolidated window for "others", or counts that are not included in windows A through D.)

Each line of windows data contains the window letter (A, B, C, etc.) followed by the window's counts per minute (cpm), two-sigma statistical uncertainty of the counts per minute, and percent of the total counts included within that window.

NOTE: The RAD7 does not store spectra from old cycles, so no spectra will print from memory even if the printer format is Long. If you need a spectrum, be sure you print while the test is still running.

If no data are available to print, the RAD7 will beep and display No tests stored.

To abort a printout, press the menu key, then press the printer paper advance button.

2.3.3 Data Com

The RAD7 has an RS232 port that can transfer data to your computer. Status must be Idle.

To send a run of data to the serial port, select >Data Com followed by the two-digit run number. When ready, push [ENTER].

The following message will appear on the display as the data is sent:

```
Data transfer ...
```

When the data transfer finishes, the RAD7 will beep.

To enable your PC to receive data, appropriate software should be running. A terminal emulation program, or CAPTURE, the data link software provided with the RAD7, may be used. See Chapter 6 for more details on data communication.

2.3.4 Data Summary

To print a summary report and time graph of a run's data, select >Data Summary followed by the two-digit run number. The following information will be printed:

```
Run 31
Begin!01-Jun-99!  12:49
Serial!     00500
Cycles = 048
Mean:!0.77 pCi/l
S.D.:!0.27 pCi/l
High:!1.41 pCi/l
Low:! 0.20 pCi/l
```

where:
Line 1 is the run number.
Line 2 shows the date and time of the first reading.
Line 3 is the serial number of the instrument.
Line 4 is the number of completed cycles in the run.
Line 5 is the arithmetic mean (or "average") of the radon concentrations recorded.
Line 6 is the standard deviation of the readings taken during the run.
Lines 7 and 8 are the highest and lowest radon concentrations.

Following Line 8 is a bar graph of radon concentration through time. Time-of-day is printed along the left-hand edge of the graph. If there is only one cycle of data, the bar graph will not print.

This printout procedure has been programmed into several protocols. When you choose one of the pre-programmed protocols, this report is printed out automatically at the end of the run, together with a cumulative spectrum.

2.3.5 Data Free

To determine the amount of free memory available for storing new radon readings, select >Data Free, and push [ENTER].

For about two seconds, the display will look something like this:

```
910 cycles free.
```

The RAD7 can store up to 999 cycles of data. As the memory fills with data, the Data Free indicator decreases. If the Data Free indicator reaches 000, any subsequent attempt to store data to memory will result in a "memory full" error.

Keep your eye on this indicator to avoid embarrassment! When the amount of free memory gets uncomfortably low (i.e. 200 or less), consider deleting un-needed old data to open up space for new data. See Data Delete and Data Erase.

2.3.6 Data Delete

To delete an entire run of data, select>Data Delete followed by the two-digit run number.

The display will prompt you for confirmation:

```
Delete run 31?
No
```

Press [→] to find Yes, then press [ENTER] to delete the run's data from memory and free the space for new data. No other run's data will be affected.

After deletion of a run's data, any attempt to retrieve the data will result in a No tests stored message. The main purpose of the Data Delete command is to selectively free up memory space for new tests. Do not confuse Data Delete with Data Erase, which wipes out all runs of data from memory. See also Data Free, Data Renumber, and Data Erase.

2.3.7 Data Renumber

Select `>Data Renumber` to renumber remaining runs into consecutive order after deleting one or more runs. This allows you to free up run numbers for new runs to be added, which is necessary when the run number approaches 99.

Say you have used all 99 runs and you wish to clear out some space for new runs. Furthermore, you have decided that you no longer need the data from runs 01 to 10. Delete these runs using `Data Delete`. Now select `>Data Renumber` to renumber runs. Runs 11 to 99 become runs 01 to 89, leaving 90 to 99 free to take new data.

The Data Renumber command does not free up memory space, only run numbers. The 999 cycle memory limit remains whether or not all 99 runs have been used.

2.3.8 Data Erase

Select `>Data Erase` only if you wish to completely wipe all data from the entire RAD7 memory. Data Erase deletes all runs and resets the current run/cycle number to 0101.

Select `>Data Erase`. The RAD7 will ask for confirmation:

`Erase all Tests?! No`

Press [➔] to find `Yes`. Press [ENTER] to complete the erasure. Use with caution!

2.4 Setup

The Setup group of commands configures the RAD7 to perform tests according to your needs. The RAD7 remembers all Setup parameters when it is turned off, so access the Setup commands only to change parameters.

Setup includes a 1-step `>Setup Protocol` command to configure the most frequently used parameters (Cycle time, Recycle number, Mode setting, and Pump setting) according to preset "protocols". These standard preset protocols include (None), Sniff, 1-day, 2-day, Weeks (that is, indefinite), User (which lets you preset your own), Grab, Wat-40 and Wat250 (for use with the RAD H_2O), and Thoron.

The special command `>Setup SavUser` defines the user protocol according to the current parameter settings.

2.4.1 Setup Protocol

Select `>Setup Protocol` to automatically load in a group of predefined Setup parameters under one of the standardized protocols, or the User protocol. If you do not wish to select a protocol, you may abort the command by pressing the menu key, and no parameters will be changed.

Table 2.4.1 Preset protocols

	Cycle	Recycle	Mode	Thoron	Pump
Sniff	00:05	0	Sniff	Off	Auto
1-day	00:30	48	Auto	Off	Auto
2-day	01:00	48	Auto	Off	Auto
Weeks	02:00	0	Auto	Off	Auto
User	xxx	xxx	xxx	xxx	xxx
Grab	00:05	4	Sniff	Off	Grab
Wat-40	00:05	4	Wat-40	Off	Grab
Wat250	00:05	4	Wat250	Off	Grab
Thoron	00:05	0	Sniff	On	Auto

A Recycle number of 00 indicates indefinite test length. The test ends only if the operator intervenes, or if the RAD7 memory fills.

2.4.2 Setup Cycle

How long a test do you want, and how often do you want the RAD7 to take a reading (a cycle)? A typical radon test is made up of many cycles.

Select `>Setup Cycle` to adjust the Cycle time, or integration time, for a single radon reading. The Cycle time can be adjusted anywhere from two minutes to 24 hours. For continuous monitoring, the Cycle time is usually 30 minutes or longer. For radon sniffing, the Cycle time is usually 5 or 10 minutes. For thoron sniffing, the cycle time may be as little as 3 minutes.

Upon selection of `>Setup Cycle`, push [ENTER] and you will see something like this:

Cycle: 00:30

First, select the number of hours (00 to 23), and press [ENTER]. Then select the number of minutes (00 to 59) and press [ENTER].

Remember that a run includes many cycles in sequence, and the total duration of the radon test is determined by the Cycle time multiplied by the number of cycles, or Recycle number. To adjust the Recycle number, use the >Setup Recycle command.

2.4.3 Setup Recycle

How long a test do you want, and how often do you want the RAD7 to take a reading (a cycle)? You determine the length of your test by choosing both the length and number of cycles. If you make a reading every 30 minutes, you will need 48 cycles to get a 24-hour test. In this case, 48 is the Recycle number.

Use >Setup Recycle to set the total number of cycles in a complete run. Multiply Cycle time by Recycle number to determine the total duration of the run.

Select >Setup Recycle. Push [ENTER] and you will see something like this:

Recycle: 48

Use the arrow keys to change the Recycle number, and press [ENTER] to complete the selection. Recycle number may be set from 00 to 99.

If 00 is selected, then the number of cycles is assumed to be infinite. Select 00 if you want the RAD7 to collect data indefinitely, or to go beyond the 99th cycle. After the 99th cycle, the RAD7 will then simply start a new run, and continue collecting data. Data collection will stop only when the operator intervenes, or when the memory completely fills up.

2.4.4 Setup Mode

Select >Setup Mode to change the RAD7 mode of operation. Five modes are available: Sniff, Auto, Wat-40, Wat-250, and Normal.

SNIFF mode is used when you want to follow rapid changes of radon concentration. In SNIFF mode, the RAD7 achieves rapid response to changing radon levels by focusing on the 3-minute polonium-218 alpha peak, calculating the radon concentration on the basis of this peak alone.

In NORMAL mode, the RAD7 achieves higher statistical precision by counting both polonium-218 and polonium-214 alpha peaks.

AUTO mode automatically switches from SNIFF mode to NORMAL mode after three hours of continuous measurement. This allows time for the equilibrium of the longer-lived radon daughter isotopes. The earliest part of the run will have the benefit of the SNIFF mode's quick response, while the latter parts of the run will benefit from the NORMAL mode's superior statistical precision.

We recommend that the AUTO mode be used for all screening tests and any tests to measure the average concentration over a period of time. With the AUTO mode there is no need to throw away the first three hours of data, or to calculate adjustments to correct for disequilibrium. The mean concentration reported in the run summary should accurately reflect the actual mean. SNIFF mode should be used where the goal is to follow, and measure, rapid changes in the radon concentration.

Wat-40 and Wat250 make calculations of the radon concentration in 40 mL and 250 mL water samples, respectively. They require the RAD H_2O water accessory kit to aerate the water under the controlled conditions necessary for these calculations.

2.4.5 Setup Thoron

Select >Setup Thoron. Push [ENTER] and you will see:

Thoron: Off

Use the arrow keys to toggle between On and Off, and press [ENTER] to complete the selection.

With Thoron On, the calculated thoron concentration will be printed during continuous data logging, or in subsequent printing of data. Also, if the pump is in AUTO mode, it will be directed to pump continuously during the thoron measurement.

Note that the thoron calculation assumes a standard setup for the measurement. A small drying tube, three feet of vinyl tubing, and the inlet filter, should be used. Typically, the small drying tube is held in the hand, and used as a wand. If the laboratory drying unit is used instead of the small drying tube, it creates additional sampling delay, which allows more of the thoron to decay before reaching the RAD7, reducing the sensitivity of the measurement to about half that of the standard setup.

The only difference between Sniff protocol and Thoron protocol is that this setting, ‘Setup Thoron’, is Off in Sniff protocol and On in Thoron protocol (See Setup Protocol, Chapter 2.4.1).

2.4.6 Setup Pump

Select >Setup Pump to change the Pump setting. Four settings are available: Auto, On, Grab, and Off.

Auto means that the RAD7 switches the pump on and off according to a predetermined pattern that allows for sufficient sampling of air while conserving battery charge and pump wear.

In Auto pump setting, the pump always switches on for 4 minutes at the beginning of a new test cycle to ensure a good initial sample. If the humidity in the sample cell remains above 10%, then the pump stays on to allow the cell to dry out. Then the pump runs for just one minute in every five, until the end of the cycle.

On means the pump is always on, whether the RAD7 is counting (Live) or not (Idle).

Grab initiates a standard grab sampling sequence at the beginning of a run. When you start a new run with the pump set to Grab, the pump will run for exactly 5 minutes. This is followed by a five-minute equilibrium delay, after which the counting period begins. The pump does not run at all during the counting period. As usual, you can determine the length of the count period by multiplying the cycle time by the recycle number. The total time to complete a test is the pump sample time (5 minutes) plus the delay period (5 minutes) plus the count period. Note that the Grab, Wat-40 and Wat250 protocols, under >Setup Protocol, above, all use this pump setting.

Off means the pump is always off.

Use Auto pump setting for routine radon testing. The RAD7 has been factory calibrated with the pump in this setting.

2.4.7 Setup Tone

Select >Setup Tone to choose the audible tone type. Three settings are available: Off, Chime, and Geiger. Off means the beeper remains quiet. Chime means the beeper will sound only at the end of a cycle, and is otherwise silent. Geiger means the beeper will emit a chirp whenever a particle is detected, much like the familiar Geiger counter. But unlike a Geiger counter, the pitch of the chirp depends on the energy of the alpha particle. A trained ear can distinguish "old" radon from "new" radon by the sound of the chirps. The thoron beep is the highest pitch. In the Geiger setting, anyone will recognize a radon "gusher" by the rapid-fire chirping the RAD7 produces.

2.4.8 Setup Format

Select >Setup Format to change the way data are printed out. Four settings are available: Short, Medium, Long, and Off.

Short causes the RAD7 to print results in an abbreviated form. Three lines of printed text contain a cycle's most important data: the run/cycle number, radon concentration and two-sigma uncertainty, units and mode, time and date, temperature, relative humidity (internal), and battery voltage.

Medium and Long printouts include seven additional lines of data: total counts, livetime, and counts per minute for five alpha energy windows. These seven lines are the raw data from which the radon concentrations shown in the first line of the printout are calculated.

The Long format, when printing from a test in progress (Live) includes a graph of the alpha energy spectrum. Since spectra cannot be saved to long-term memory, the spectrum will not be printed when retrieving past data.

Off means that no data will print out at the end of each cycle, but the summary and cumulative spectrum will print at the end of the run (if the printer is set up and switched on).

2.4.9 Setup Units

Select `>Setup Units` to change the measurement units with which the RAD7 reports radon concentration and temperature. First, enter the radon concentration unit (pCi/L = picoCuries per liter, Bq/m3 = Becquerels per cubic meter, cpm = counts per minute, #cnts = number of raw counts). Next, enter the temperature unit (_F = degrees Fahrenheit, _C = degrees Celsius or Centigrade).

PicoCurie is the favored unit of radon activity in the U.S., while Becquerel is the favored unit in Europe and Canada. 1 pCi/L equals 37 Bq/m^3. "Counts per minute" is the direct output of the RAD7 while "number of raw counts" is the raw direct output. With livetime, mode, and calibration factor, one can convert from any of these units to any other, but it is usually easier to let the RAD7 do the work.

The choice is retroactive. Change the unit using the `>Setup Units` command, then print out the same data. Everything will print as before, but in the new units.

2.4.10 Setup Savuser

Select `>Setup SavUser` to program the special User protocol according to the present Setup parameters. You must answer Yes, and push `[ENTER]`, to confirm that you wish to change the User protocol. The purpose of this command is to give you an opportunity to customize a protocol according to a set of favorite parameters. Thereafter, it's a cinch to return to the same set of parameters; simply select `>Setup Protocol [➔] User`.

The User protocol has many possible applications. One RAD7 owner uses her instrument for 3-day screening tests. To make the setup easy, she programs the User protocol with the parameters for a 72-hour screening test. To do this, she first sets up all the parameters as she wants them. She enters 2 hour for the Cycle time, 36 for the Recycle number, Auto for the Mode setting, Off for thoron, and Auto for the Pump setting.

Finally, to program the User protocol with these values, she selects `>Setup SavUser` and answers Yes to the confirmation question. After that, she can easily return to the 72-hour protocol by selecting `>Setup, Protocol, User`, any time she wishes.

2.4.11 Setup Clock

Use `>Setup Clock` to change time zones, go in or out of daylight savings time, or to synchronize the RAD7 clock with another clock. The Real Time Clock (RTC) will maintain time-of-day and calendar date for as long as 10 years, and is accurate to within one minute per month at room temperature.

Select `>Setup Clock` to set the time and date of the RAD7 clock. You will see:

```
Time:    15:05:34
```

The time is listed with hours first, then minutes, then seconds. The arrow keys can be used to change each value. Holding an arrow key down will cause the number to change quickly. The cursor (blinking square) will start on the hour. Set the correct number with the arrow keys, then push `[ENTER]` to confirm. Do the same for the minutes and seconds.

Next you should see:

```
Date:   13-DEC-11
```

Dates are listed with the day of the month first, then the month, then the year. As with the RAD7 clock, the date is set by using the arrow keys to change each value. Press `[ENTER]` after each figure is set to move on to the next.

2.4.12 Setup Review

The >Setup Review command allows you to display and print a listing of the current instrument settings, including Date and Time, Protocol, CycleTime, Recycle, Mode, Thoron, Pump, Tone, Format and Units. Thus you can check that the instrument is set up properly, and confirm this, in hard copy, right on the data printout.

2.5 Special

The Special menu offers access to a selection of additional commands, provided by the RAD7's RADLINK remote control software. If for any reason RADLINK is not present, you will see the following when entering the Special menu:

```
Not installed.
Install?   No
```

Use the arrow keys to toggle between Yes and No. If you confirm Yes, the RAD7 will sit, waiting for a data string at the RS232 port. If necessary, DURRIDGE will complete this RADLINK installation process when the RAD7 is returned for calibration.

If RADLINK is installed, then >Special opens a menu of special commands available from the keypad of the RAD7. All the commands, both standard and special, will also be accessible from a remote PC, either directly, or by modem connection.

The following command set are those available with RADLINK version 0252. Earlier versions will have a subset of these.

2.5.1 Special Ident

Output the RAD7 identification sequence, including firmware version, hardware model number, unit serial number, and last calibration date.

2.5.2 Special SPrOn

Re-direct subsequent output from the infrared printer to the serial port. In other words, everything that would ordinarily be printed will shoot out the serial port, but nothing will be printed, even when you say "Print". One reason to use this might be to move the data very quickly into a computer without waiting for the (slow) infrared printer link. You can cancel the re-direction order and restore the use to the infrared printer with the "Special SPrOff" command. When you turn off the RAD7 and turn it on again, it always restores output to the infrared printer.

Note that the spectra that would be printed on the infrared printer are not sent to the serial port by Special SprOn.

2.5.3 Special SPrOff

Cancel the printer to serial port re-direction, so that output can go to the printer again.

2.5.4 Special SetBaud

Set the serial port bit rate. The following standard speeds are available: 300, 600, 1200, 2400, 4800, 9600, and 19,200 bps. The other communication settings are always 8 bit, no parity, and 1 stop bit. The RAD7 remembers the serial port speed when you power down. Note that at the highest serial speed settings the RAD7 may not be able to keep up with incoming character strings unless the characters are "paced". An "echo-wait" strategy will avoid this problem. Also note that the RAD7 recognizes XOFF/XON flow control protocol when sending data.

2.5.5 Special Status

Gives a snapshot of the RAD7 status page, including run and cycle numbers, countdown timer, last reading, temperature, humidity, and so on. This is basically the same information that you can get with "Test Status", but it gives the data in one shot and does not continue to update every second.

2.5.6 Special Start

Same as "Test Start" (see Chapter 2.2.2, Test Start), but does not go into a continuously updating status display.

2.5.7 Special Stop

Same as "Test Stop" (see Chapter 2.2.2 Test Stop).

2.5.8 Special Comspec

Output the current test data, including the counts in all 200 alpha energy bins. These counts can be imported into a spreadsheet program and displayed as a graph of the energy spectrum.

2.5.9 Special ComAll

(Version 0244/940221 or later) - Output complete set of RAD7 test data (up to 1000 readings) to the serial port in comma delimited format.

2.5.10 Special SPrAll

Output complete set of RAD7 test data (up to 1000 readings) to the serial port in standard, readable 24 column printer format, without affecting the infrared printer.

2.5.11 Special S-Load

Used to load special software into the RAD7 through the serial port.

2.5.12 Special Version

Output the special extension version number.

2.5.13 Special Model

Output the RAD7 hardware version number.

2.5.14 Special Serial

Output the RAD7 unit serial number.

2.5.15 Special Beep

The RAD7 gives an audible beep tone. Does not make any sound if the tone setting is "Off".

2.5.16 Special Relays

Access the RELAYS set of commands. At the end of every cycle, if the function is enabled, the RAD7 will set or reset two external relays according to the individually set thresholds and the measured radon level. The commands consist of 'relay1', 'relay2', 'enable', and 'disable'. Use the arrow keys to scroll between these commands. Relay1 permits the user to set a level, above which the RAD7 will turn on relay1, and below which it will turn the relay off. Relay2 does the same for the second relay. 'Enable' causes the function to go into effect. Note that the command to the relays is sent after the RAD7 has finished printing data at the end of the cycle. 'Disable' stops the RAD7 from sending any commands to the relays.

2.6 Infrared Printer

The RAD7 uses an infrared link to print to the supplied printer. Note that all references to the RAD7 printer in this manual refer to the Chamjin I&C New Handy printer, model 700-BT . The most significant difference between this printer and the previously supplied, now obsolete HP 82240B printer is that the HP printer had to have external 12V power supplied in order to stay awake for more than 10 minutes between printouts. The Chamjin printer does not accept external power.

The printer should be placed on the RAD7 face plate, between the green lines as indicated. Because the print mechanism uses thermal technology, only thermal paper will work. Detailed instructions are provided in the Chamjin printer manual.

If the printer is placed in position and switched on before switching on the RAD7, it will print out identity information and a review of the setup, before the RAD7 goes to >Test. It is good practice to do this if the measurement data are to be printed out, because it automatically provides a header for the data printout, with instrument identity and setup:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 20-MAY-11
Last used
!  FRI 21-MAY-11! 17:30

Current settings
!  FRI 21-MAY-11! 19:09

Protocol: 2-Day
Cycle: 00:60
Recycle: 48
Mode: Auto
```

```
Thoron: Off
Pump: Auto
Tone: Geiger
Format: Short
Units: pCi/L    EC
```

At the end of every cycle, the printer will print the data of that cycle, according to the format setting. In short format, it prints:

```
0102    2.69   " 0.73    p    Sniff
!  FRI   21-MAY-99     19:41
!  26.8 EC    RH: 7%    B:7.06V
```

With the run and cycle number, radon level, two-sigma uncertainty, units and mode in the top row, date and time in the second, and temperature, humidity and battery voltage in the third.

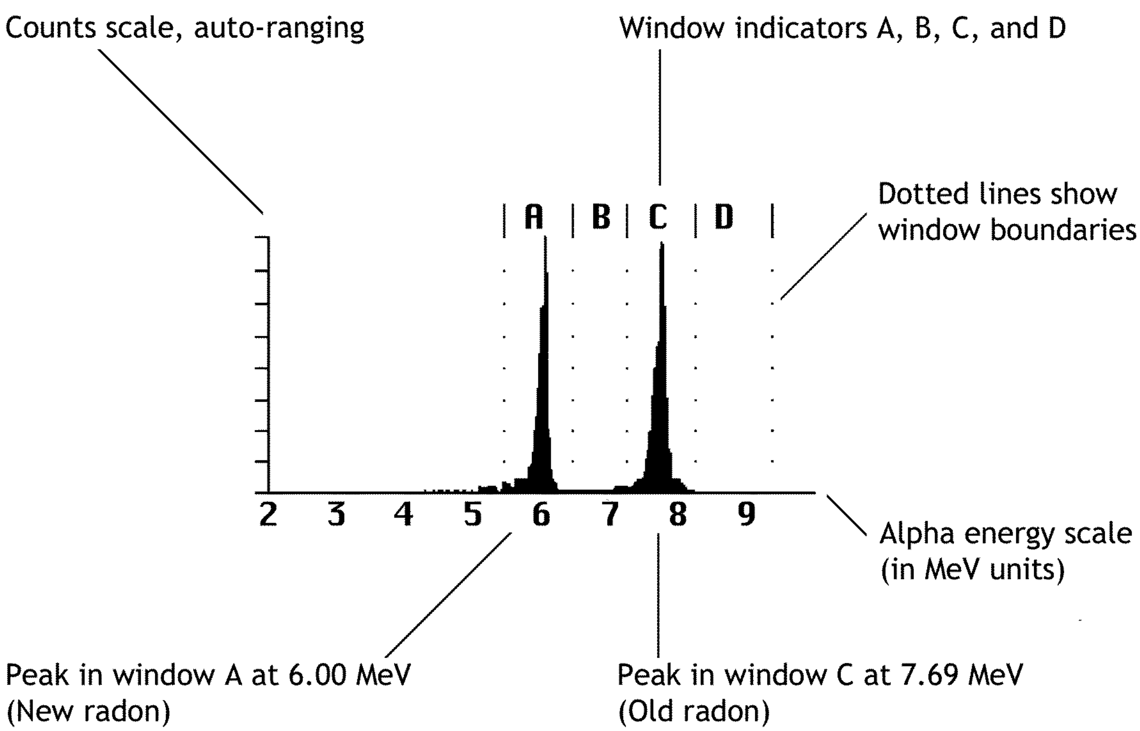
Medium format adds:

```
Total Counts:     357.
Livetime:!  28.2 min
A:!5.74" 0.98 cpm!45.4%
B:!0.32" 0.29 cpm!2.5%
C:!6.13" 1.01 cpm!48.5%
D:!0.00" 0.14 cpm!0.0%
O:!0.46" 0.34 cpm!3.7%
```

Where the lifetime is the actual time spent waiting for an event, slightly less than the elapsed time. The windows, A, B, C, D, and all the rest, O, correspond to the different alpha energies in the spectrum.

Long format adds, to the short and medium formats, a printed spectrum of the alpha energies, as shown below.

At the end of a run, the printer will print a summary, see figure in Chapter 1.4. It will include an average of the radon concentrations, the high value, low value and standard deviation. These are followed by a bar chart, showing the variation of radon concentration from cycle to cycle throughout the run. Finally, it prints a cumulative spectrum, showing the distribution of energy of all the alpha decays counted during the run. This spectrum is very informative. It gives a good indication of the condition of the instrument and the quality of the measurement. It is a useful habit to look at the cumulative spectrum from time to time, just to be sure that it has not changed in character.



Alpha Energy Spectrum

3. BASICS OF *RAD7* TECHNOLOGY: HOW IT WORKS

3.1 Introduction

This chapter deals with a number of fundamental facts concerning radon and thoron, their measurement in general and their measurement, specifically, with the RAD7. It is not necessary to master the underlying physics to become proficient in the use of the instrument, but some understanding of what is happening is helpful.

It is recommended that the user read the entire manual, including this chapter, on first acquiring the instrument, and then again after gaining some experience in the field.

3.2 Radon Decay Chain

When the earth was formed, billions of years ago, there were probably many radioactive elements included in the mix of material that became the earth. Three, of interest, have survived to this day, namely uranium-235, uranium-238, and thorium-232. Each has a half life measured in billions of years, and each stands at the top of a natural radioactive decay chain.

A radioactive element is unstable. At some indeterminate moment, it will change to another element, emitting some form of radiation in the process. While it is impossible to predict exactly when the transformation of an individual atom will take place, we have a very good measure of the probability of decay, within a given time slot. If we started with a very large number of atoms of a radioactive element, we know quite precisely how long it would take before half those atoms had decayed (though we could not identify the decaying atoms individually, beforehand). This time interval is called the half-life of that particular element.

A natural radioactive transformation is accompanied by the emission of one or more of alpha, beta or gamma radiation. An alpha particle is the nucleus of a helium atom. It has two protons and two neutrons. Thus an 'alpha decay' will reduce the atomic number by two and reduce the atomic weight by four. A beta particle is an electron, with its negative charge. Thus a beta decay will increase the atomic number by one and leave the atomic weight unchanged. A gamma ray is just a packet of energy, so a gamma decay by itself would leave both the atomic number and atomic weight unchanged.

A decay chain is a series of distinct transformations. A uranium-235 nucleus goes through a series of 11 transformations to become stable lead-207. A thorium-232 nucleus goes through 10 transformations to become stable lead-208. And a uranium-238 nucleus goes through 14 transformations to become stable lead-206.

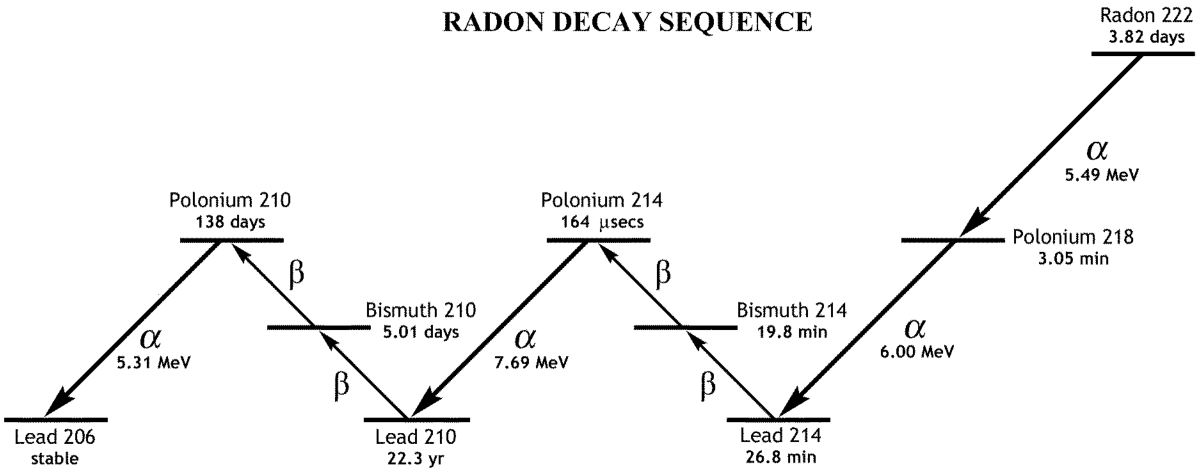
All three of these natural decay chains include isotopes of radon. Radon-219, or "actinon", is a link in the uranium-235 chain. You will probably never encounter actinon in indoor air, due to its scarcity and short half-life. Radon-220, or "thoron", is part of the thorium-232 decay chain. You will sometimes encounter thoron in indoor air, particularly near radon entry points, and, more often, in soil gas. Radon-222, or familiar "radon", is part of the uranium-238 decay chain. You will almost always be able to detect radon-222 in indoor air, outdoor air, and soil gas.

The radon isotope is the first element, in each of the decay chains, that is not a metal. It is, in fact, an inert, or "noble", gas. So it can escape any chemical compound its parent (radium) was in, and diffuse into the air.

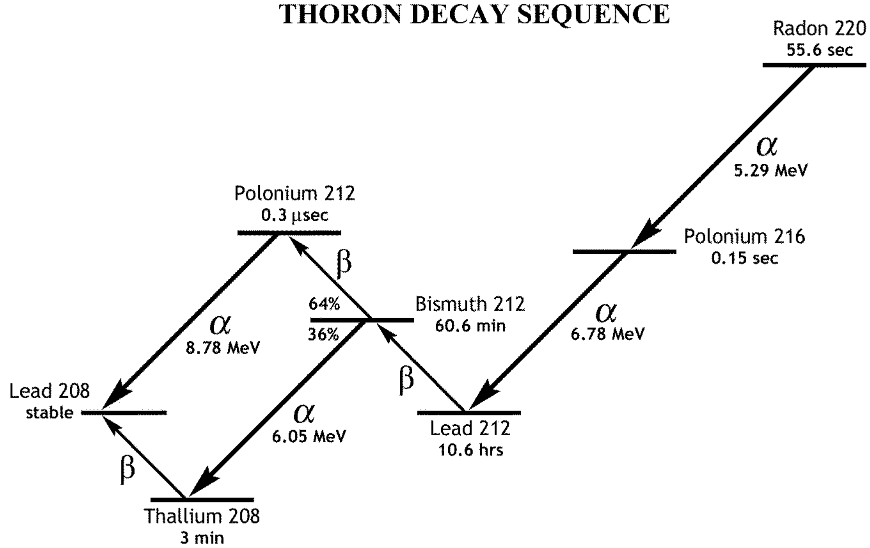
To focus on these inert gases, the thoron and radon decay chains, shown below, are those parts of the thorium-232 and uranium-238 decay chains that include just these radioactive gases and their short-lived progeny.

It may be noted that only alpha decays change the atomic weight, and then only in steps of four. Thus the atomic weights of all the members of the radon-220, thoron, decay chain are divisible by four, while none of the radon-222 are.

RADON DECAY SEQUENCE



THORON DECAY SEQUENCE



Radon and Thoron decay chains

3.2.1 Radon-222 (Radon)

Every nucleus of radon-222 eventually decays through the sequence polonium-218, lead-214, bismuth-214, polonium-214, and lead-210. With each transformation along this path the nucleus emits characteristic radiations: alpha particles, beta particles, or gamma rays, or combinations of these. The RAD7 was designed to detect alpha particles only, so we will emphasize alpha radiation .

Radon-222 is an inert gaseous alpha-emitter that does not stick to or react with any materials. It has a half-life of 3.82 days. A particular radon nucleus may decay at any time, but it is most likely to decay between now and 8 days (two half-lives) from now. When the radon nucleus decays, it releases an alpha particle with 5.49 MeV of energy, and the nucleus transforms to polonium-218. The polonium nucleus can never go back to radon again. Polonium atoms are metals and tend to stick to surfaces they come in contact with, e.g., a dust particle in the air, or a wall, or the inside of your lung!

Polonium-218 nuclei have a short half-life, only 3.05 minutes, which means that most of them will decay within 6 minutes of their formation. The average polonium-218 nucleus lives for only 4.40 minutes before it decays (1.443 times the half-life gives the mean life). Like radon, polonium-218 emits an alpha particle when it decays, but with an energy of 6.00 MeV rather than radon's 5.49 MeV.

When polonium-218 decays, it transforms to lead-214, also a radioactive solid. But lead-214 has a half-life of 26.8 minutes, and it emits beta radiation rather than alpha radiation. When lead-214 decays, it becomes bismuth-214, also a radioactive solid and a beta emitter. Bismuth-214 has a half-life of 19.8 minutes, and transforms to polonium-214 when it decays.

Polonium-214 is a bit different. It has a half-life of only 164 microseconds (0.000164 seconds) and it emits a 7.69 MeV alpha particle when it decays. When polonium-214 decays, it becomes lead-210, which has a half-life of 22.3 years. This means that an average lead-210 nucleus takes 1.443 times 22.3 years, or 32.2 years, to decay. Because of its long half-life, we usually ignore lead-210 as a factor in radon measurement, though it adversely affects the background of some instruments (not the RAD7).

Lead-210 eventually undergoes beta decay to Bismuth-210 which quickly (5 days half-life) undergoes a further beta decay to Polonium-210. Polonium-210 has a half-life of 138 days and decays with a 5.30 MeV alpha particle to Lead-206, which is stable. The 5.30 MeV alpha particle from Polonium-210 creates unwanted background in most radon monitors, but not in the RAD7.

3.2.2 Radon-220 (Thoron)

Similarly to radon-222, every radon-220 (thoron) nucleus eventually decays through a sequence of 5 transformations to Lead-208. The main distinction is the very different half lives involved.

Thoron has a half life of only 55.6 seconds. It emits a 6.29 MeV alpha particle and transforms to polonium-216, which in turn has only a 0.15 second half-life before emitting a 6.78 MeV alpha particle and transforming to Lead-212.

Lead-212 hangs around for a long time, with a half-life of 10.6 hours. It transforms by beta decay to bismuth-212, which, in turn, has a half life of 60.6 min.

Bismuth-212 has a 2:1 split, with two thirds transforming by beta decay to polonium-212 and one third transforming by 6.05 MeV alpha decay to thallium-208. The polonium-212 decays immediately to lead-208, emitting an 8.78 MeV alpha particle in the process, while the thallium-208, with a half-life of 3 min, undergoes a beta decay to the same destination, lead-208.

3.3 Continuous Monitors

There are several types of continuous radon monitors on the market. Nearly all of these are designed to detect alpha radiation, but not beta or gamma radiation. Why? Because it is very difficult to build a portable detector of beta or gamma radiation that has both low background and high sensitivity.

Three types of alpha particle detectors are presently used in electronic radon monitors:

1. Scintillation cells or "Lucas cells"
2. Ion chambers
3. Solid state alpha detectors.

Each of these types has advantages and disadvantages relative to the others. All of these types can be used for low background alpha particle counting.

The DURRIDGE RAD7 uses a solid state alpha detector. A solid state detector is a semiconductor material (usually silicon) that converts alpha radiation directly to an electrical signal. One important advantage of solid state devices is ruggedness. Another advantage is the ability to electronically determine the energy of each alpha particle. This makes it possible to tell exactly which isotope (polonium-218, polonium-214, etc.) produced the radiation, so that you can immediately distinguish old radon from new radon, radon from thoron, and signal from noise. This technique, known as alpha spectrometry, is a tremendous advantage in sniffing, or grab-sampling, applications. Very few instruments other than the RAD7 are able to do this.

A distinction should be made between true, real-time continuous monitors, and other instruments and devices. With a continuous monitor, you are able to observe the variation of radon level during the period of the measurement. This can sometimes show big swings in radon concentration and may allow you to infer the presence of processes influencing the level. For good data, it is important that there be sufficient counts to provide statistically precise readings. Devices which give just a single, average reading, or whose precision is inadequate except after a long measurement time, are not, in this sense, continuous monitors.

Another important parameter is background. This is the reading given by the instrument when there is no radon in the air sample. For low level continuous monitoring, it is necessary that the background be extremely low and stable. Because of the high quality alpha detector, and unique, real-time spectral analysis, the RAD7 background is vanishingly small, and is immune to the buildup of lead-210, which plagues other instruments.

3.4 Sniffers

Sniffing means taking quick, spot readings. Thus you can get a rough idea of the radon level, without waiting for a full, 48-hour, EPA protocol test. The technique is often used to locate radon entry points in a building.

Any fast-response, continuous radon monitor, with a pump, can be used for sniffing. However, there are some factors to consider: One is the rate of recovery after exposure to high radon levels. When the sniffer finds a radon gusher, the whole radon decay chain builds up inside the instrument, and the various daughters become well populated. If the sniffer now moves to a low level region, it will take many hours for the lead/bismuth/polonium-214 daughters to decay away. In the RAD7 this doesn't matter, because, in SNIFF mode, it looks only at the polonium-218 decays, and ignores the polonium-214 decays left over from previous sniffs. The polonium-218 has a three-minute half life, so the RAD7, sniffing for radon, has a 15 minute response time to both sudden increases and sudden decreases in level.

Unique to the RAD7 is the ability to sniff for thoron. Polonium-216 has a 150 ms half life, so the instrument response is virtually instantaneous. The only delay is the time required to put the air sample into the measurement chamber, which is about 45 seconds.

Another factor, when sniffing, is the vulnerability (of other instruments) to lead-210 buildup. Only with the RAD7 can you continue to sample high levels, without having to worry about increasing the background.

3.5 Working Level

Radon concentrations are determined by measuring the radioactivity of the radon or by measuring the radioactivity of the radon decay products. Instruments that measure radon decay products in the air are called "working level" monitors. Working level monitors sample air through a fine filter and then analyze the filter for radioactivity. The radon progeny are metal and they stick to the filter and are counted by a working level instrument. Radon-222, an inert gas, passes through the filter, so it is not counted in such an instrument. Therefore, a working level instrument measures the radon progeny concentration (polonium-218, etc.), in the air, but not the radon gas concentration.

The RAD7, on the other hand, measures radon gas concentration. Radon daughters do not have any effect on the measurement. The RAD7 pulls samples of air through a fine inlet filter, which excludes the progeny, into a chamber for analysis. The radon in the RAD7 chamber decays, producing detectable alpha emitting progeny, particularly the polonium isotopes. Though the RAD7 detects progeny radiation internally, the only measurement it makes is of radon gas concentration.

In short, the RAD7 does not measure radon daughter concentrations (working levels), only radon gas concentrations.

3.6 RAD7 Solid-State Detector

The RAD7 's internal sample cell is a 0.7 liter hemisphere, coated on the inside with an electrical conductor. A solid-state, Ion-implanted, Planar, Silicon alpha detector is at the center of the hemisphere. The high voltage power circuit charges the inside conductor to a potential of 2000 to 2500V, relative to the detector, creating an electric field throughout the volume of the cell. The electric field propels positively charged particles onto the detector.

A radon-222 nucleus that decays within the cell leaves its transformed nucleus, polonium-218, as a positively charged ion. The electric field within the cell drives this positively charged ion to the detector, to which it sticks. When the short-lived polonium-218 nucleus decays upon the detector's active surface, its alpha particle has a 50% probability of entering the detector and producing an electrical signal proportional in strength to the energy of the alpha particle. Subsequent decays of the same nucleus produce beta particles, which are not detected, or alpha particles of different energy. Different isotopes have different alpha energies, and produce different strength signals in the detector.

The RAD7 amplifies, filters, and sorts the signals according to their strength. In SNIFF mode, the RAD7 uses only the polonium-218 signal to determine radon concentration, and the polonium-216 signal to determine thoron concentration, ignoring the subsequent and longer-lived radon daughters. In this way, the RAD7 achieves fast response to changes in radon concentration, and fast recovery from high concentrations.

3.6.1 RAD7 Calibration and Data Correction

The RAD7 depends on calibration to determine the radon and thoron concentrations it measures. Built into the RAD7 firmware are three sensitivities:

1. Sniff sensitivity, counting only 218-Po for fast response.
2. Normal sensitivity, counting both 218-Po and 214-Po decays for higher precision.
3. Thoron sensitivity, counting 216-Po decays for thoron.

In calibration, the RAD7 is exposed to a known concentration of radon (or thoron) and the count rates are measured. Your radon calibration certificate gives the two radon sensitivities.

For thoron calibration, a separate calibration letter gives the calibrated thoron sensitivity. If thoron calibration is not conducted, the thoron sensitivity is estimated to be half the radon Sniff sensitivity, which is usually a reasonable estimate. In either case, when making a thoron measurement the RAD7 has to be set up and used in Thoron Protocol for the thoron reading to be valid.

In addition to the bare count rates in the three windows, there are various corrections and calculations that may be applied to calculate more precise radon and thoron concentrations. Some of these corrections are made automatically by the RAD7 itself. Others are optionally applied using DURRIDGE's CAPTURE software, after the data has been downloaded onto your computer.

The RAD7's internal corrections and calculations are:

a. Spill from window C into window B. This is important when measuring thoron in the presence of radon-222. The DURRIDGE calibration system has no thoron in the sample air and it is therefore easy, during calibration, to measure the spill and calculate it as a fraction of the count rate in window C.

b. Bi-212 alpha decays occurring in the A window. This is important when measuring low radon concentrations in the presence of high thoron. The Bi-212 count rate is approximately half the Po-212 count rate, whose decays are in the D window. So, again, it is easy to measure the Po-212 count rate and use it to determine the Bi-212 count rate and consequently the correction to be applied to the 218-Po count rate in window A.

c. In WAT-40 and WAT250 protocols (used when recording RAD H_2O data), the RAD7 calculates the radon concentration of a water sample based on the radon concentration in the air loop. A known calibration factor is applied to achieve the necessary conversion.

After RAD7 data has been downloaded onto a computer, the DURRIDGE CAPTURE software can perform additional calculations and corrections:

a. B window to A window spill correction. This is important when measuring low radon levels in the presence of high thoron.

b. Humidity correction. This is essential if the desiccant becomes completely hydrated during a measurement.

c. Radon-in-water calculation. With the RAD AQUA and Radon-in-Water Probe, the equilibrium ratio between the radon concentration in the water and that of the air entering the RAD7 is a function of the temperature at the air/water interface. CAPTURE can be given the necessary temperature information via a data file produced by a temperature logger, or it can use the air temperature as measured by the RAD7, or it can be given a single temperature value. This temperature information is then used along with the radon-in-air readings to calculate the radon concentration of the water.

d. Meaningful thoron threshold: The spill from window C to window B produces counts that must be deducted from the B count rate before the thoron concentration can be determined, but those spill counts have statistical uncertainty. That means that a count rate in B that is slightly above the calculated spill from C may, in fact, be merely a statistical variation of the spill rather than actual thoron. The spill, therefore, increases the uncertainty in the thoron reading. CAPTURE calculates a 'meaningful thoron threshold', taking into account the statistical uncertainty in the spill, and will display this threshold on the graph if so instructed.

e. Forced Sniff mode: For long-term measurements, the RAD7 is normally put in Auto mode, in which the measurement starts in Sniff mode so as to achieve a fast initial response, before automatically switching to Normal mode after three hours, when the 214-Po decays have nearly reached equilibrium with the radon concentration. This assumes that the radon concentration is steady. If it appears that rapid changes in radon concentration were taking place, the user can, in CAPTURE, force the graph to display the data as if the RAD7 stayed in Sniff mode throughout the measurement, and thus see the rapid changes with a measurement time constant of just 12 minutes.

3.7 RAD7 Spectrum

The RAD7 spectrum is a scale of alpha energies from 0 to 10 MeV. Of particular interest are the radon and thoron daughters that produce alpha particles in the range of 6 to 9 MeV.

When the radon and thoron daughters, deposited on the surface of the detector, decay, they emit alpha particles of characteristic energy directly into the solid state detector. The detector produces an electrical signal. Electronic circuits amplify and condition the signal, then convert it to digital form. The RAD7 's microprocessor picks up the signal and stores it in a special place in its memory according to the energy of the particle. The accumulations of many signals results in a spectrum.

The RAD7 divides the spectrum's 0 to 10 MeV energy scale into a series of 200 individual counters, each representing a 0.05 MeV channel. Whenever the RAD7 detects an alpha particle, it increments one of these 200 counters by one.

Every so often, the RAD7 manipulates, condenses, prints out and stores data to long-term memory. Then it resets all 200 counters to zero, and begins the process anew.

The idealized spectrum of a 6.00 MeV alpha emitter looks like a single needle-thin spike at exactly 6.00 MeV.

Although the RAD7 approaches this ideal, the actual spectrum shows a broadened peak centered at or near 6.00 MeV with a characteristic "tail" that stretches into lower energy channels. Electronic noise in the detector and amplifier causes the peaks to widen, while alpha particles that enter the detector at glancing angles cause the tail. Higher than normal operating temperatures tend to increase electronic noise, and so increase the width of the peaks.
A combination of different alpha emitters appears on the spectrum as a series of different peaks. For example, a combination of equal amounts of Po218 and Po214 (as would occur in the case of radon daughter equilibrium) appears as twin alpha peaks. One peak (Po218) is centered at 6.00 MeV, while the other (Po214) is centered at 7.69 MeV.

The second example spectrum, shown in Chapter 3.13, is the characteristic signature of radon at equilibrium with its alpha emitting daughters. We would expect to see a spectrum like this after several hours at a constant radon level. The 5.49 MeV alpha particle directly emitted by radon-222 does not appear on the RAD7 spectrum, because it was created in the air, not on the surface of the detector. The radon-222 atom is inert and electrically neutral, and cannot be attracted to the solid state detector. Only after it decays to polonium-218 does the atom become positively charged and is thus driven to the detector surface.

The RAD7 spectrum shows radon daughters, but not radon itself. Do not confuse the RAD7's spectrum with that of a working level instrument. The alpha peaks may appear the same, but the RAD7 is really measuring radon gas, not working level.

3.8 Windows

The RAD7 groups the spectrum's 200 channels into 8 separate "windows" or energy ranges. Window A, for example, covers the energy range of 5.40 to 6.40 MeV. So window A includes the 6.00 MeV alpha particle from polonium-218. The first step toward converting raw spectral data to radon measurement is to add up all the counts in each window and divide by the detector "livetime" or duration of active data collection. The RAD7 microprocessor does this task and stores the results to memory in this form. You can recall and print window data from past measurements. The RAD7 adds windows E, F, G, and H together to form window O (for "other") before storing the data to memory. Spectrum printouts clearly mark windows A, B, C, and D with dotted lines.

Each window's function:

A. Radon Sniffer Mode counts. The total counts of alpha particles from the 3-minute, 6.00 MeV, Po218 decay.

B. Thoron 1 Window. The total counts in the region of the 0.15 second, 6.78 MeV decay of Po216. This window lies between windows A and C of the radon groups and may have some counts from spill-over from adjacent windows.

C. Radon Po214 counts. The total counts of the 7.69 MeV alpha particles from the decay of the great-great granddaughter of radon, which has an effective half-life of nearly an hour.

D. Thoron 2 Window. The total counts in the region of the effective 8.78 MeV decay of Po212, which has a half-life of about 10 hours.

E. High Energy Window. A diagnostics window that normally has close to zero counts. If the counts in this window are a large fraction of the counts in A or B or C or D, the RAD7 is probably not working properly.

F. Low Noise counts. A diagnostics window that gives the total counts in the first 10 channels. The count rate in Window F is a measure of the noise in the system. The counts may be high if the RAD7 is operated at very high temperatures.

G. Medium Noise counts. A diagnostics window that gives the total count in the region around channels 30 to 40. Window G normally has few counts, even when Window F shows a high count rate.

H. High Noise or Po210 Window. The total counts in the region of the 5.31 MeV alpha particle due to Po210 (polonium-210), the grand-daughter of Pb210 (lead-210). Since lead-210 (22 year half-life) results from the decay of the radon progeny we measure, this isotope will build up on the detector's sensitive surface through sustained measurement of very high radon concentrations, or many years of normal use. This window is not used in calculating radon levels, so the RAD7 will function well even with this isotope present, and the background will not be affected.

O. Composite window for "Others". The RAD7 groups windows E, F, G, and H together to form the composite window O. Window O catches all the counts that did not go into the major windows A, B, C, and D. If window O consistently receives more than 30% of the total counts, you should inspect the spectrum printout for signs of trouble.

3.9 Isotope Equilibrium

Take a RAD7 that is completely clean, with no radon or daughters inside. What does the detector see? Close to nothing. Less than one alpha count per hour, due to unavoidable contamination of the materials of the instrument's construction. That is the instrument's intrinsic background. It is ignored by most people as of no consequence. Intrinsic background may add 0.01 pCi/L to a typical measurement, far below the radon concentration of outdoor air (usually 0.10 to 1.00 pCi/L).

Now introduce some radon into the RAD7. What do you see? At first, maybe nothing. But within a few minutes, you begin to get counts in the A window. The RAD7 chirps merrily with each count. That's polonium-218, a result of the decay of radon-222 within the RAD7 sample chamber.

For the first 5 minutes or so, the count rate increases, then begins to approach a steady level. After about 10 minutes, we say that the polonium-218 daughter has reached close to equilibrium with the radon-222 parent.

Equilibrium is when the activity of the daughter stabilizes, neither increasing or decreasing. At this point, nearly all of the counts land in window A, and you see a single peak in the spectrum printout.

But the total count rate is still increasing, more slowly now. You begin to see counts appear in window C. Just a few, but more and more of them over the course of the next hour or two. After 3 hours or so, we reach full equilibrium, when the activities of all the daughters stabilize. Now the spectrum shows the characteristic twin peaks: polonium-218 in window A and polonium-214 in window C. The peaks are of almost identical size.

Now flush the RAD7 with fresh, radon-free air. The count rate in window A immediately begins to drop, just as fast as it rose when you first put the radon in. Without radon inside the RAD7, there is no source to replace the polonium-218 that decays. So the polonium-218 disappears with its characteristic half-life of 3.05 minutes.

After 3.05 minutes, the count rate in window A is half of what it was before. After 6.10 minutes, the count rate is half of that, or one-quarter of what it was before. You get the picture. After 10 minutes, there are hardly any counts at all in window A. Not so for window C, however. The spectrum still shows a single strong peak in window C.

The peak in Window C takes hours to disappear. After half an hour, the count rate in window C has not even halved. Polonium-214 may have a very short half-life, but its parents, lead-214 and bismuth-214, certainly don't. One has a half-life of 26.8 minutes, and the other has a half-life of 19.8 minutes. And they are sequential, which makes matters worse.

After you completely remove the radon, it may be a good 3 or more hours before the counts really die down in window C. We call window C the "old radon" window, since it represents counts from radon that was present in the RAD7 an hour or more before.

The effects of time in windows B and D, is similar, but much more pronounced. There is no delay in the RAD7 to polonium-216, so the count rate in window B is always in equilibrium with the thoron gas in the measurement chamber. In contrast, there is a 10-hour half life in the decay chain down to polonium-212, so it will take days for window D to reach equilibrium. Window D is, therefore, not counted when sniffing for thoron.

Note however, that for every 66 counts in window D, there will be 34 counts in window A. This is because of the two-way split from Bismuth-212. So, in calculating radon concentration, the RAD7 corrects the counts in window A for any thoron daughters that show in window D.

3.10 Modes: Sniff and Auto

"Old" radon daughters can be a real pain in the neck if you can't tell them apart from "new" radon. Most radon monitors don't help you at all here, but the RAD7 does. Waiting around for equilibrium is also a trial if it means sitting around for more than 2 hours. It is possible to calculate your way out of that problem, but the "old" radon always comes back to bite you. With the RAD7, the solution is simple and painless. Put the RAD7 in SNIFF mode.

SNIFF mode means that the RAD7 calculates radon concentration from the data in window A only. It ignores window C. Now the instrument responds to changes almost instantaneously. Hit a "hot spot?" No problem. In SNIFF mode, you can purge the sample chamber and, in 10 minutes, you're ready to measure low levels again with reasonable accuracy. You can move from point to point in minutes, looking for radon entry points in foundation cracks or test holes.

For continuous monitoring in one location over many hours, NORMAL mode is the way to go. NORMAL mode means that the RAD7 uses both radon peaks, A and C, to calculate concentration. With double the count rate, you increase the precision of the measurement. In indoor environments, the radon concentrations rarely fluctuate quickly enough to justify using SNIFF mode for continuous monitoring.

The best of both worlds is provided by AUTO mode. Here, the RAD7 starts a test run in SNIFF mode, and then, after three hours, switches automatically to NORMAL mode. In this way, the first few cycles give readings without any bias from either “old” radon daughters left on the detector, or the slow build-up to reach equilibrium in window C, while the rest of the readings benefit from the higher precision given by twice the number of counts in each cycle.

For real-time monitoring, you are always better off to leave the mode in AUTO. The RAD7 is up to speed quickly, and is not influenced by old measurements. The final average of the run is therefore more accurate and more reliable.

CAPTURE can read a data file and force SNIFF mode presentation of the data, allowing the user to change the setting retrospectively.

Thus if, on looking at data taken in NORMAL mode, there is what appears to be a rapid change in radon concentration, changing to forced SNIFF mode presentation in CAPTURE will permit another look at the changes with better time resolution.

3.11 Background

"Background" in a radon detector refers to spurious counts that occur even in the absence of radon. Background can arise from the properties of the instrument or its components, other forms of radiation in the instrument's environment, or contamination of the instrument.

The RAD7's design makes it much less susceptible to background than other radon monitors, but one should still be aware of background in the RAD7 to avoid mistakes. The following list gives possible sources of background in the RAD7:

3.11.1 Short-lived Radon and Thoron Daughters

These are by far the most important components to background in the RAD7. Radon and thoron daughters that normally build up on the RAD7's solid state alpha detector continue to produce alpha counts for some time after the radon and thoron gases have been removed from the instrument. These lingering daughters can greatly confuse the result when you try to measure a low radon sample immediately after a high radon sample.

Many radon detectors require that you wait for the daughters to decay away (about three hours) before counting another sample. With the RAD7, however, you can go from high to low concentrations in a matter of minutes by counting in SNIFF mode, since the RAD7 distinguishes the different alpha-emitting daughters by their alpha energy. The resulting measurement responds with a 3.05 minute half-life. Thus, 10 minutes after the radon has been removed from the instrument, the background will have been reduced by more than 90% and you can count a new sample.

Thoron daughters are worse behaved than radon daughters. One thoron daughter, Lead-212, has a half-life of 10.6 hours, so that, with other radon monitors, if you build up huge amounts of this daughter, you may have to wait one to two days before using your radon instrument again. The RAD7's ability to distinguish daughters by their alpha energy almost always makes it possible to continue working.

3.11.2 Adsorbed Radon Gas

Radon atoms can adsorb on or absorb into internal surfaces of the RAD7, on the inside of tubing or on desiccant granules. This radon can stay behind after you purge the instrument, then desorb (or out-gas) from these surfaces and enter the sample cell volume. This effect is ordinarily negligible since only a small fraction of the radon ever becomes adsorbed. But at very high radon concentrations (over 1000 pCi/L), even a small fraction can be significant, and you can expect to see some lingering radon after purging the instrument.

The best solution is to purge for 10 minutes every few hours until the count rate goes down. Even in the worst possible case, the radon must decay with a 3.82 day half-life, so you will eventually be able to use the instrument again.

3.11.3 Intrinsic Background

Due to very low concentrations of alpha emitting contaminants in the materials of the RAD7's construction, you can expect to get as much as one count every two hours (0.009 cpm) without any radon present. This count rate, corresponding to about 0.02 pCi/L, is low enough to neglect when doing routine indoor radon work. But for very low-leveled outdoor radon levels, or special clean room applications, this background may be significant. With painstaking technique, and long-term monitoring, it can be measured. Very low level readings can then be corrected for background, bringing the detection threshold of the instrument down below 0.02 pCi/L.

3.11.4 Long-lived Radon Daughters

After many years of use at elevated radon levels, your RAD7's detector will accumulate lead-210, an isotope with a 22-year half-life. Though Lead-210 is itself a beta emitter, one of its daughters is polonium-210, which produces a 5.3 MeV alpha particle. The RAD7 is able to distinguish this isotope by its energy, and exclude it from all calculations. We do not expect lead-210 buildup to contribute significantly to background in the RAD7, even after years of ordinary use.

3.11.5 Contamination by Radon, or Thoron, Producing Solids

If radon- or thoron-producing solids, such as radium-226 or thorium-228, become trapped in inlet hoses or filters, they may emanate radon or thoron gas that will be carried through the filters and into the instrument. Certain dusty soils may contain enough of these isotopes to make this scenario possible. If you suspect this kind of contamination, please call DURRIDGE. We would like to discuss your experience with you and help you solve your problem.

3.11.6 Other Alpha Emitters

As long as you filter the incoming air stream, there is little or no possibility for contamination of the instrument with other alpha emitters.

Virtually all solids will be stopped by the inlet filters. The only naturally-occurring alpha-emitting gas other than radon and thoron is radon-219, or "actinon." Actinon, which has a very short half-life (less than four seconds), results from the decay of naturally-occurring uranium-235. But since uranium-235 is so much less abundant than uranium-238 (the ancestor of radon-222), we do not expect to ever see actinon in significant quantities apart from even more significant quantities of radon.

3.11.7 Beta and Gamma Emitters

The RAD7's solid state alpha particle detector is almost completely insensitive to beta or gamma radiation, so there will be no interference from beta-emitting gases or from gamma radiation fields. The most likely effect of high levels of beta or gamma radiation will probably be an increase in detector leakage current and increased alpha peak width. Typical environmental levels of beta and gamma emitters have absolutely no effect on the RAD7.

3.12 Precision & Accuracy

3.12.1 Dry operation

"Precision" means exactness of measurement with regard to reliability, consistency and repeatability. "Accuracy" means exactness of measurement with regard to conformity to a measurement standard. An accurate instrument is necessarily precise, but a precise instrument can be inaccurate (due to mis-calibration, for example).

As long as the operator follows consistent procedures, counting statistics will dominate the RAD7's precision. Environmental factors have proven to be much less significant over normal ranges of operation. Aside from precision, the most important factor in RAD7 accuracy is calibration.

DURRIDGE calibrates all instruments to a set of four "master" instrument with a calibration precision of about 1%. The master instruments have been calibrated by way of inter-comparison with secondary standard radon chambers designed by the U.S. EPA. We estimate the accuracy of the master instrument to be within 4%, based on inter-comparison results. We estimate the overall calibration accuracy of your RAD7 to be better than 5%. We look forward to new developments in calibration standardization and traceability, which we expect will help improve calibration accuracy.

The table below summarizes the precision of the RAD7 according to the contribution of counting statistics. Counting statistics depend on sensitivity (calibration factor) and background count rate. The RAD7's intrinsic, or "fixed," background count rate is so low as to be a negligible contributor to precision, for the range of radon concentrations covered by the table. Environmental and other factors may affect precision by as much as 2%. The uncertainty values reported by the RAD7 are estimates of precision based on counting statistics alone, and are two-sigma values, as are the values in the following table.

Table: 3.12 Typical RAD7 precision based on counting statistics only.

NORMAL mode with sensitivity 0.500 cpm/pCi/L. Table values are two-sigma uncertainty (or 95% confidence interval) in units of pCi/L (percent).

	1 pCi/L	4 pCi/L	20 pCi/L	100 pCi/L
1 hr	0.37 (37%)	0.73 (32%)	1.64 (8.2%)	3.65 (3.7%)
2 hr	0.26 (26%)	0.52 (13%)	1.15 (5.8%)	2.58 (2.6%)
6 hr	0.15 (15%)	0.30 (7.4%)	0.67 (3.4%)	1.49 (1.5%)
24 hr	0.07 (7.4%)	0.15 (3.8%)	0.33 (1.7%)	0.74 (0.7%)
48 hr	0.05 (5.3%)	0.10 (2.6%)	0.23 (1.2%)	0.53 (0.5%)
72 hr	0.04 (4.3%)	0.09 (2.1%)	0.19 (1.0%)	0.43 (0.4%)

3.12.2 Humidity Correction

Much of the superior functionality of the RAD7 is a result of the high-precision real-time spectral analysis it performs. The high resolution of the energy spectrum is obtained by precipitating the radon daughters, formed by the decay of radon, right onto the active surface of the alpha detector. The high sensitivity of the RAD7 is a result of the large collecting volume of the measurement chamber. The combination of a precipitation process and large collecting volume means that humidity inside the measurement chamber will affect the sensitivity of the instrument. The affect is a function of the absolute humidity; specifically, ions in the presence of water vapor will attract water molecules, as they are polar, until a cluster of 6 - 10 water molecules gathers around each of them. These cluster molecules move more slowly in the electrostatic field and thus there is more time for the 218-Po atoms to become neutralized en route to the detector surface, and therefore lost. So with high humidity the sensitivity of the instrument drops. In addition the high voltage (2,200V) that maintains the electrostatic field is from a high impedance source. Excessive humidity inside the chamber makes it more difficult to maintain the high insulation resistance necessary.

At normal room temperature and with good desiccant in the air sample path, the humidity in the measurement chamber at the start of a measurement will quickly be brought down below 10% RH and will eventually settle below 6%. In these conditions the collection has maximum efficiency and there is no humidity correction required. Should the desiccant expire and/or should the operating temperature rise well above normal room temperature, the absolute humidity may become significant and a humidity correction may be required to compensate for the drop in sensitivity.

While high humidity reduces the sensitivity of a RAD7, CAPTURE offers an automatic correction of the data, bringing readings back close to dry values. Please note, however, that the precision will be degraded, compared with readings taken in dry conditions. See Chapter 6.

3.12.3 Concentration Uncertainties

Obtaining accurate readings of a low radon concentrations often requires long cycle times, because when there are zero or very few counts within a given timeframe, the statistical uncertainty is proportionately high. Radioactive decays obey Poisson statistics, where the standard deviation (one-sigma) is the square root of the count. However, at very low counts Poisson statistics underestimates the uncertainty. To compensate, the RAD7 defines sigma as 1 + SQR(N+1), where N is the number of counts. Thus when there are no counts, instead of reporting a nonsensical zero uncertainty, the RAD7 reports an uncertainty value based on a two-sigma, 95% confidence interval, equivalent to +/- 4 counts for a cycle in which zero counts were recorded.

Typically, an average count rate of 0.2 cpm (i.e. one count in five minutes) would indicate a radon concentration of about 36 Bq/m3, but sigma would be 1 + SQR(N + 1) or 2.4 counts, and the reported two-sigma value would be 4.8 counts. Thus after 5 minutes, the uncertainty would be reported as 0.96 cpm, or +/- 173 Bq/m3.

Large uncertainty values are often the product of the fact that it is impossible to measure low radon concentrations quickly. Greater certainty can be achieved by increasing the cycle time and/or by averaging multiple cycles. In Sniff mode, 218-Po (which has a 3.05 min half life) takes more than 10 minutes to reach equilibrium with the radon concentration in the RAD7 chamber. Note that in Sniff protocol, which uses 5-minute cycles, it is important not possible to start averaging the readings to reduce uncertainty only after the first two cycles.

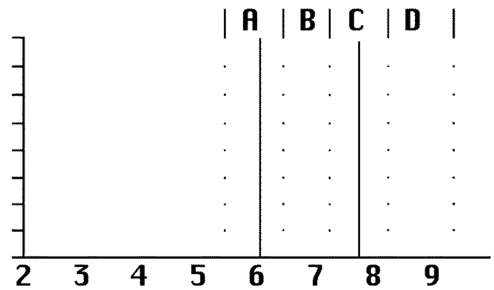
It is possible to measure radon and thoron concentrations simultaneously, but since their requirements are sufficiently different, it may be desirable to optimize the measurement first for one gas and then for the other. For radon, it is advisable to select SNIFF protocol and then change the cycle time to 10 minutes. After starting a run, the first reading can be ignored, with only the second and subsequent readings being used. As more readings are recorded, more precise concentrations will be obtainable.

Occasionally, a concentration uncertainty greater than the base value may be reported, e.g. 0.00 +/- 83.1 Bq/m3. Such values are typical for cycles containing zero counts. This should not be taken to suggest that a negative concentration may have occurred. The RAD7 does not report different positive and negative uncertainties, and it is expected that the user will recognize that the negative uncertainty can never be greater than the base value of the reading.

3.13 Spectrum Examples

3.13.1 Operational Radon Spectra

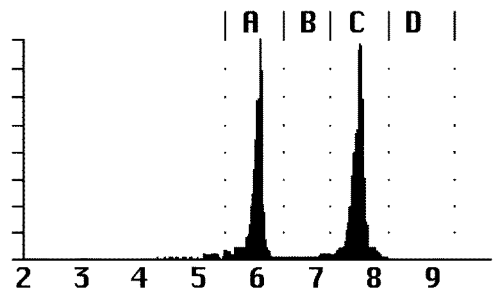
A. Idealized radon in equilibrium



This is what you would see if both the detector and electronics reached theoretical perfection. At full equilibrium, both peaks are at the same height.

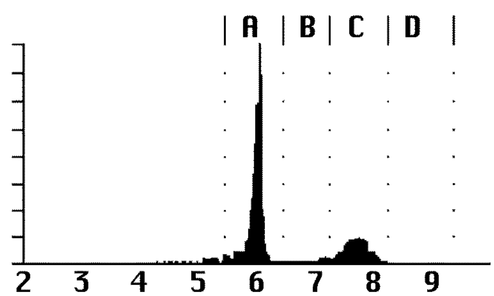
A 6.00 MeV Po218
C 7.69 MeV Po214

B. Radon in full equilibrium



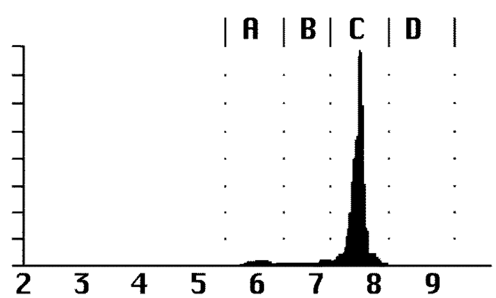
After more than three hours at a constant radon level. The count rate in window C is about the same as in window A.

C. New radon



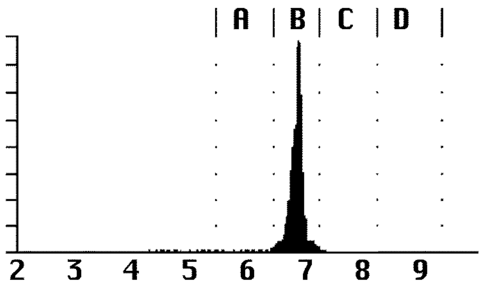
The RAD7 spectrum after less than one hour of exposure to radon. The peak in window C is just beginning to grow in, but its count rate is still much less than in window A.

D. Old radon



The RAD7 spectrum after purging the instrument with radon-free air for more than 10 minutes, following exposure to radon.

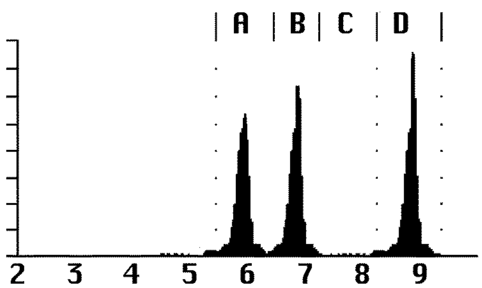
3.13.2 Thoron Spectra



A. New thoron

The RAD7 spectrum while continuously sampling thoron laden air

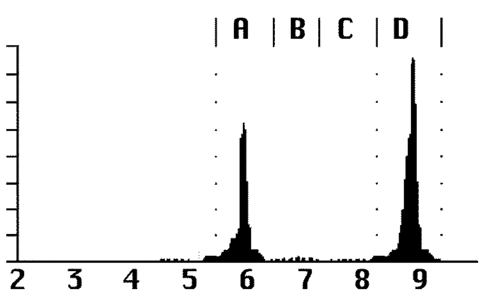
B 6.78 MeV Po216



B. Thoron in equilibrium

The spectrum after continuously sampling thoron laden air for more than 12 hours. The count rate in window A should be about half the count rate in window D

A 6.05 MeV Bi212
B 6.78 MeV Po216
D 8.78 MeV Po212



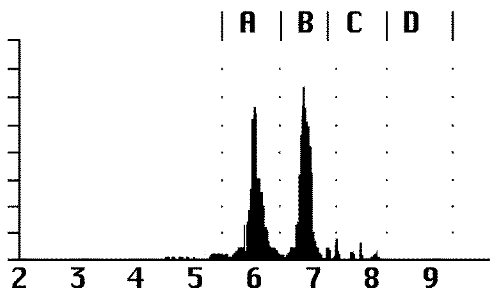
C. Old thoron

The spectrum after discontinuing a lengthy sampling of thoron laden air. The thoron peak, B, disappears immediately. The remaining two peaks decay together with a 10.6 hour half-life. The count rate in window A should be about half the count rate in window D.

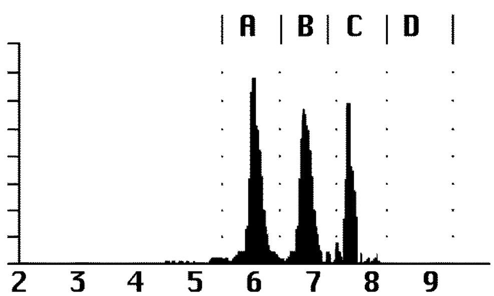
3.13.3 Combination Spectra

Radon and thoron spectra can add together to form combination spectra. Peaks in window B and/or D come from thoron, while a peak in window C comes from radon. The peak in window A is usually entirely from radon, but if there is a peak in window D, then there will a contribution of about half the D count rate to the peak in window A.

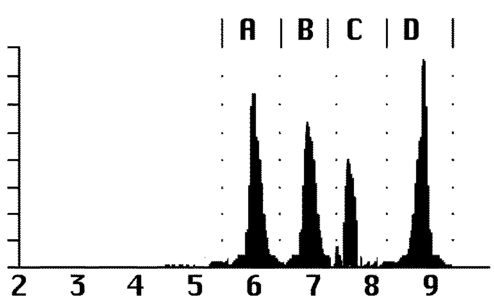
The RAD7 takes this into account, and always adjusts the window A count rate to correct for the Bi212 count, before calculating the radon concentration. The spectra below have comparable amounts of radon and thoron, but you will usually see one of the two much stronger than the other.



A. New radon with new thoron.



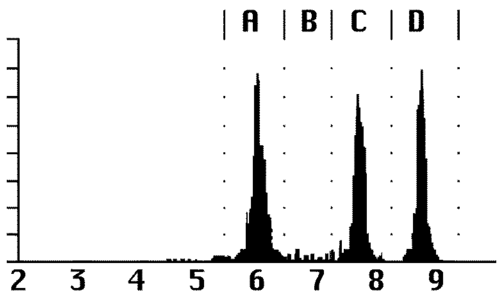
B. Equilibrium radon with new thoron



C. Equilibrium radon with equilibrium thoron.

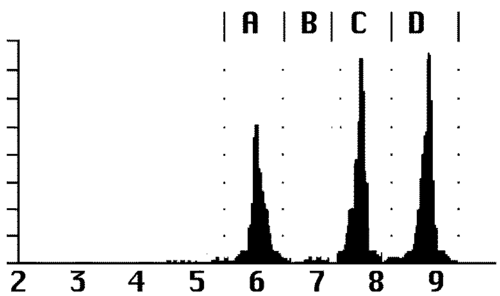
The count rate in window A is roughly the rate of window C plus half the rate of window D.

A 6.00 MeV Po218
+6.05 MeV Bi212
B 6.78 MeV Po216
C 7.69 MeV Po214
D 8.78 MeV Po212



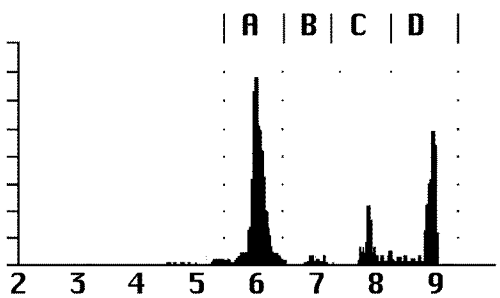
D. Equilibrium radon with old thoron

The count rate of A is roughly the rate of window C plus half the rate of window D.



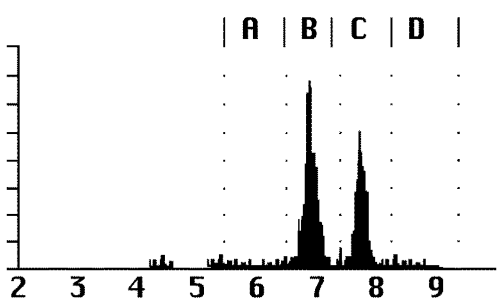
E. Old radon with old thoron.

The count rate in window A is no more than about half the count rate of window D.



F. New radon with old thoron.

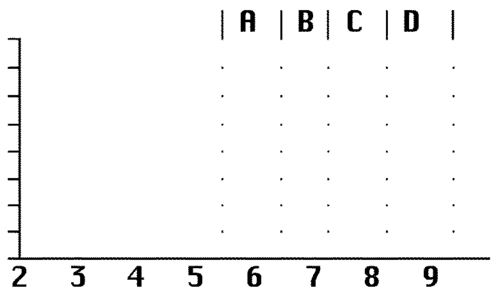
Looks like an old thoron spectrum, but the count rate of window A is significantly more than half the count rate of window D.



G. New thoron with old radon.

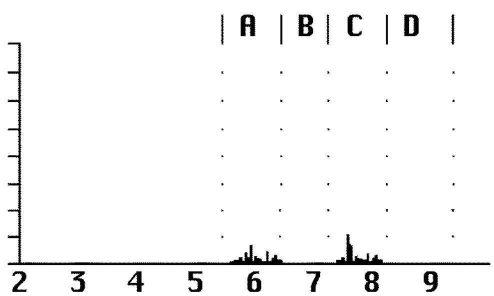
3.13.4 Pathological Spectra

If any of the following occur, and an external cause is not identified, the user should contact DURRIDGE immediately. Email to service@durridge.com would be a good way to initiate the contact.



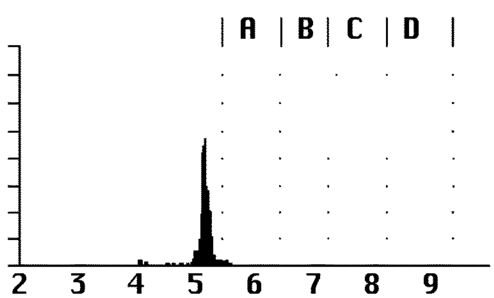
A. No counts.

Try a longer counting time. If there is not a single count in an hour, that is clear indication of instrument malfunction.



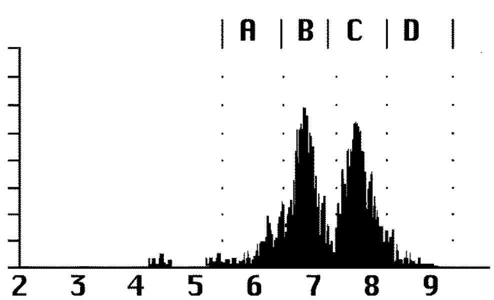
B. Few counts.

Normal for low radon levels and short counting times. Abnormally low counts could be caused by disruption of the air flow, or by malfunction in the high voltage circuit.



C. Lead-210/polonium-210.

A persistent peak at 5.3 MeV will develop from many years of regular use, or from sustained exposure to very high radon levels. It results from the buildup of lead-210 on the detector surface. Lead-210 has a 22 year half-life. It is not a problem for the RAD7 because the peak is outside window A, and thus does not contribute to the background.

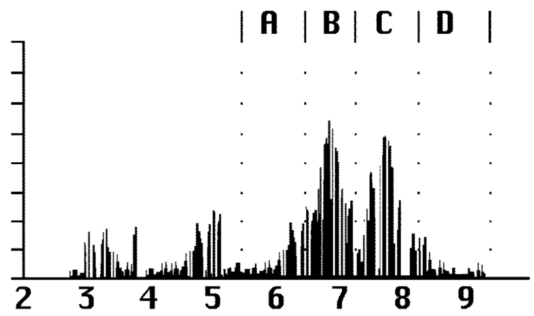


D. Wide alpha peaks.

Typically caused by electronic noise in the system. May be associated with vibration, with high operating temperature, or with degradation of the surface barrier detectors used in older model RAD7's, built prior to 1996.

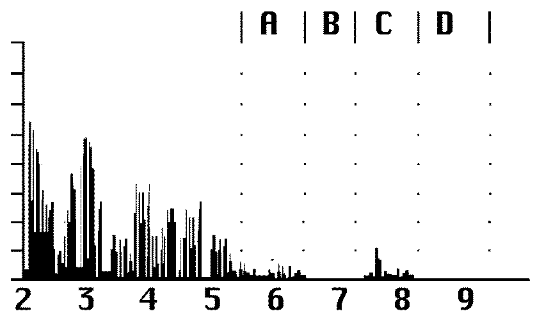
E. Smeared spectrum.

Alpha peaks cannot be discerned by the eye. Severe electronic noise.



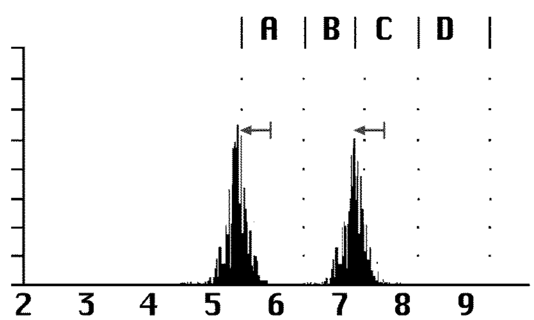
F. Low energy noise.

Independent of radon or thoron, such electronic noise may be intermittent or be associated with vibration.



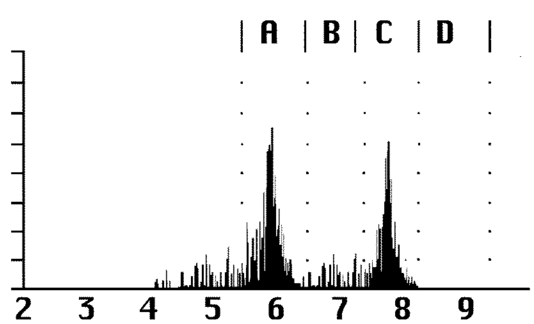
G. Shifted peaks.

Peaks appear normal, but are shifted in position. Shows a malfunction of the RAD7, which should be returned to DURRIDGE for service without delay.



H. Heavy tails on alpha peaks.

The peaks are narrow, but have unusually thick tails. This may be caused by electronic noise, or by malfunction of the alpha detector.



4. USING THE *RAD7*: RADON AND THORON MEASUREMENT IN AIR

4.1 Introduction

The different ways of using the RAD7 may be arranged in six categories:

(a) continuous monitoring of radon in air
(b) sniffing for radon and/or thoron
(c) testing air grab samples
(d) measuring radon in water
(e) testing soil gas
(f) measuring radon and thoron emissions from objects and surfaces.

While all six are discussed below, it is primarily categories (a) and (d) that require standard operating procedures. The other applications tend to be more interactive, and individuals will develop protocols which work best for them. This chapter focuses on using the RAD7 to measure radon and thoron in air, without the user of special hardware accessories. Chapter 5 introduces applications involving the RAD AQUA, RAD H_2O, and other DURRIDGE accessories.

4.2 Continuous Monitoring

4.2.1 Preparation

The RAD7 batteries should be fully charged so that, even if there is a power cut, the test will be completed. Similarly, there should be more than sufficient active desiccant in the Laboratory Drying Unit.

For an EPA protocol test, the house should be fully closed from 12 hours before the start of the test. This means that ALL doors and windows should be shut tight. No air exchange system, or ventilation fans, may be running.

In winter it is not difficult to satisfy this requirement. Continued operation of the furnace is permitted. Closed house conditions are usually maintained anyway, to save heating costs. Doors may be opened momentarily, for access, but should otherwise remain closed throughout the test.

In summer it may be impossible to satisfy the requirement, without the residents moving out for the duration of the test. If doors and windows are left open, it can nullify the test, except that if there is a radon problem under these conditions, then there will be a greater problem under closed house conditions.

Air conditioning often includes some fresh air ventilation, which dilutes the radon. Even if there is no ventilation, the cold air in the house will want to sink, increasing pressure in the basement, and thus reducing any flow of soil gas into the house. So air conditioning in the summer will tend to lower the radon level in the house.

For further detailed information, see the EPA "Indoor Radon and Radon Decay Product Measurement Device Protocols" publication, EPA 402-R-92-004, or view it at http://www.epa.gov/radon/pubs/devprot1.html

4.2.2 Purging

For the RAD7 to be all set to go, ready to start a test, it should be purged for at least five minutes beforehand. This may be done in the car, en route to the test site.

Locate an inlet filter, a piece of tubing with a sleeve at one end and small tube at the other, and the laboratory drying unit. Connect the filter to the tubing: It should be a tight fit into the small diameter section. Remove the plastic caps from the drying unit and push the sleeved end of the tubing onto the tube connector, on the drying unit, farthest from the metal screw cap. Now attach the filter to the inlet of the RAD7.

Switch on the RAD7, push [MENU], [ENTER], [➔] four times, to see >Test Purge on the display, then push [ENTER]. The pump will start. The display will show Stop purge? No. Leave the unit purging for five minutes, or longer. When you are ready to start the test, the easiest way to stop purging is to push the Menu key, or switch off the instrument.

4.2.3 Test Location

In general, the test should be conducted in the "lowest area in the house that is used, or could be adapted for use, as a living area". This would include a full-height basement, but not a crawl space.

Place the RAD7 near the center of the room, about 3 - 4 feet above the floor. Avoid walls, vents, fireplaces, windows, draft, and direct sunlight.

Where possible, connect DC power to the RAD7, to conserve and recharge the batteries.

The air intake will be the connector of the drying unit without any tubing attached (nearest the end with the metal screw cap), or the far end of the tube if one is attached to this connector. Make sure the air intake is at least 30 inches (75 cm) above the floor, and away from the walls.

Once set up in location, let the RAD7 continue to purge until ready to start the test.

4.2.4 Test Protocol

In any location there is often a diurnal variation of radon level. It is preferable, therefore, that the test period be an exact number of whole days. The EPA protocols require an average taken over at least two days. The RAD7 gives time resolution as well. A choice must be made, therefore, of the cycle time and the number of cycles (recycle). For 24-hour and 48-hour tests, the RAD7 has preset protocols which will make the choice for you. You can always change the choices (even in the middle of a test!), and, if you wish, save your preferences as the user protocol. You may, for instance, prefer to conduct 3-day tests, and, perhaps, use 24 cycles, each 3 hours long. The longer the test, the greater the precision of the result.

For a 24-hour or 48-hour test, using the preset protocol, before starting the test, go to >Setup Protocol [➔] 1-day, or 2-day, and push [ENTER]. You need, also, to decide whether to leave the tone Off, Chime, or Geiger, and whether to have short, medium or long format of printouts at the end of each cycle, and set the parameters accordingly.

For very long term monitoring, use the Weeks protocol. This sets the RAD7 to run indefinitely, with 2-hour cycles. The internal memory capacity, of 1,000 cycles, will last nearly 12 weeks. If data is periodically downloaded to a PC, and erased from the RAD7, there is no limit to the measurement duration. With the laboratory drying unit used to dry the sampled air, the desiccant will have to be replaced every 7 to 14 days, depending on the humidity. The RAD7 needs external power for indefinite operation, but can survive, without loss of data, an interruption of power lasting up to 50 hours, or more, depending on the condition of the batteries.

For any other measurement period, you will need to set the parameters yourself. The cycle time, times the number of recycles, gives the duration of the total measurement. In almost every case, for continuous monitoring, choose [Mode Auto], [Thoron Off], and [Pump Auto].

Once the RAD7 switches (after three hours) to NORMAL mode, the counts are included from Window C, which come from Po-214 atoms. These were once radon atoms, that entered the measurement chamber as much as an hour or more beforehand. Therefore, in NORMAL mode, the RAD7 is averaging the radon concentration from less than 20 minutes ago (Po-218) with the radon concentration from less than three hours ago (Po-214). So, for a long test in NORMAL mode, the cycle time should be set to one hour, or more.

Where there is a requirement for a fast response and detailed time resolution, the cycle time may be set as short as half an hour, or even 20 minutes, but the Mode should then be set to Sniff, not Auto. Note however, that counting only Window A, and for such short periods, the number of counts per cycle will be less than for longer cycles in NORMAL mode, and so the individual readings will have more scatter. Note also that short cycle times will fill up the memory more quickly (the capacity is 1,000 cycles), use up the desiccant more quickly, and, if the printer is being used, produce more printout.

4.2.5 To Print Or Not To Print

It is not necessary to run the printer during a measurement as all data, except for the detailed spectra, are stored at the end of every cycle, and are available for printing or downloading to a PC at any time. Furthermore, with no printer and the key pad locked, it is impossible for any unauthorized snooper to read the radon concentration during the run. On the other hand, use of the printer gives a convenient and informative hard copy of the results.

For routine continuous monitoring, it is usual to set the printer format to short (Setup, Format, Short, [ENTER]).

Place the printer on the face plate and switch on. Switch the RAD7 off, then on again. Information about the RAD7, and the setup, will print out. Data will be printed at the end of every cycle, and a summary, bar chart and cumulative spectrum will print at the end of the run.

4.2.6 Running the Test

When everything is ready, start the test (Test, Start, [ENTER]). The pump will start running and the LCD display will go to the first status window.

The house should remain in closed condition for the duration of the run. At any time, the status windows can be viewed. The relative humidity, temperature and battery voltage are all parameters that are worth observing. Rising relative humidity may indicate that the desiccant is exhausted, or that there is a leak in the sample path. The temperature reading gives a base for future reference, see below. A dropping battery voltage may indicate that the power is not connected.

4.2.7 Security and Quality Control

For a good measurement, it is essential that the RAD7 (or any measurement device, for that matter) remain in its place, and the house remain closed, throughout the run.

Anti-tampering tapes are available for the windows and doors. A soft, plastic adhesive, such as Blue-Tack, HOLDIT or Tac'N Stik, under the RAD7, will stick better the first time than in subsequent placings. An experienced hand can tell if the RAD7 has been moved. But perhaps the best anti-tampering defense is the data itself. With the time resolution in the data provided by the RAD7, anomalies are clearly revealed. A sudden change in radon concentration and in air temperature, during the measurement, is a strong indication of tampering, either by moving the instrument, or by opening windows. The key-pad lock prevents tamperers from looking at the data, or interfering with the measurement.

A detailed and systematic quality control protocol must be established by any user seeking certification. This should include a description of the measurement process, and the steps taken to ensure that the readings are reproducible.

The RAD7 is too accurate for any procedure in the field to be able to verify that it is working within specifications. However, it is good practice, on a regular basis, to compare the RAD7 readings with some other device, such as a passive charcoal collector. The two devices should be placed close together, with the RAD7 sampling point near to, but not touching, the charcoal collector. The measurements should also cover the same time period. The charcoal reading may then be compared with the RAD7 mean for the period. Remember, however, that some charcoal devices, and labs, may give readings which are in error by as much as 25%. If the RAD7 and the charcoal device differ by more than 10%, repeat the comparison as soon as possible, preferably with a different charcoal device, from a different lab. Look at the RAD7 cumulative spectrum, printed out at the end of a run, to see if it appears normal. If the RAD7 mean is consistently, significantly different from the readings of other devices in side-by-side tests, or if the spectrum looks abnormal, please call , or email, DURRIDGE for advice. In any case, we recommend that the RAD7 be returned to DURRIDGE Company, for recalibration, annually.

An excellent quality test, for the RAD7, is simply an examination of the cumulative spectrum printed out at the end of every run. If the spectrum looks normal, and the humidity, temperature, and battery voltage are within normal range, then that is very strong evidence that the RAD7 is working properly, and the readings are reliable.

4.2.8 Finishing the Run

Even if no printout has been made at the end of every cycle, it is still useful to have a printout at the end of the run. If the RAD7 can be accessed before the run is finished, simply place the printer in position on the face plate and switch it on. After the last cycle is completed, the RAD7 will print the run summary, including the mean value, the bar chart of all the readings, and the cumulative spectrum. If the instrument cannot be accessed before the end of the run, the summary can be printed out later, but without the cumulative spectrum.

Switch off the printer and the RAD7. Disconnect the tubing from the desiccant and replace the plastic caps over the hose connectors. If the caps have been lost, a single piece of tubing may be attached between the two connectors, thus providing a seal to keep the desiccant dry.

Remove the inlet filter from the RAD7. It is good practice to leave the inlet filter attached to the plastic tubing. Replace the short piece of tubing connecting the inlet to the outlet. Putting the jumper between the inlet and outlet keeps the internal space of the instrument sealed, and thus dry, while still allowing air flow should the pump start running.

When moving the RAD7, please treat it with respect. It is rugged, but it is still an electronic instrument. Please avoid hard knocks and very harsh environments.

4.2.9 Examining the Data

In addition to the printout, data may be examined on the LCD, during or after a run. The records may also be downloaded to a PC, where they are then available for creating graphs and tables for printed reports.

On reviewing a set of data, first check that the relative humidity in the instrument stayed below 10% throughout the measurement. If it rose above 10%, it suggests that the desiccant was either removed, or became depleted. The RAD7 reads low if the internal RH rises above 10%.

The temperature during the measurement should remain fairly steady. Sudden changes of temperature in the record suggest that either the windows were opened, or the RAD7 was moved from its location.

If the house was not properly closed up until the measurement was started, you may expect to see a rising radon concentration during the first few hours of the run. If that is the case, any very low, early readings should be discarded in the calculation of the mean value for the house. That would mean manual calculation of the average, from the good readings. EPA protocols require at least 48 hours of continuous good data. If the house was not closed up beforehand, a 3-day test could satisfy the EPA requirement.

If the air sampling point was changed for a while, or some windows opened, during the run, you may expect to see a change in air temperature, and change in radon concentration, during that period. Simultaneous changes of these two parameters is an indicator of tampering.

4.2.10 Very Short Term Monitoring

Some Home Inspectors choose to use the RAD7 for a short-term test, just during the home inspection. This means that they have full control over the test, and they can take the RAD7 with them, when they leave, on completion of the home inspection.

They close up the house, set up the RAD7 in the basement, choose a half-hour cycle time and a total run length (recycles) of, typically, four or five cycles. At the end of the run, the RAD7 prints out a bar chart of the increasing radon concentration, at half-hour intervals. The data gives the Home Inspector, and his client, a good indication of the radon situation. Adding 50% to the final half-hour reading gives an estimate of what would be the average radon level, for closed house conditions. If, during those two hours of the test, the radon concentration climbs towards, or over, the 4 pCi/L mark, then they can be confident that, with a full, EPA protocol test, covering 2 days, or more, the result would surely exceed the 4 pCi/L action level.

4.3 Sniffing

4.3.1 Why Sniff?

There are two main reasons for sniffing. One is to obtain a quick, spot reading of radon concentration, as a simpler substitute for grab sampling, and the other is to locate radon entry points. For each application, the method will be slightly different.

4.3.2 Locating Radon Entry Points

There is a very good chance that thoron will be present in the soil gas entering the building. It will, however, be detectable only close to the entry points. Thoron, therefore, if it is in the soil gas, can be considered as a tracer for fresh radon gas. Sniffing to locate radon entry points may, therefore, be focused on detecting thoron, if it is there, to speed, and simplify, the process. The same procedure will also give radon concentrations, provided that the sampling point is kept at one spot for at least 15 minutes.

4.3.3 Preparation

Detailed instructions are given in Chapter 1.5. Choose Thoron in the Setup Protocol menu, and set the Tone to Geiger. Employ a small drying tube and, preferably, just a yard of tubing to the inlet filter.

4.3.4 Purging

While it is always good practice to purge the instrument before using it, there is less necessity before sniffing. In SNIFF protocol, the pump runs continuously, so the air sample will be flushed through every minute or two, and the measurement chamber will quickly dry out, even if the relative humidity starts above 10%.

To bring the humidity in the instrument down without wasting desiccant, the RAD7 outlet may be connected to the open end of the drying tube, making a closed loop, during the purge cycle.

After detecting high concentrations of radon and/ or thoron, it is good practice to purge the instrument immediately after use.

4.3.5 Running the Test

With the RAD7 strap over one shoulder, holding the small drying tube as a wand, start the test. The first status window will be displayed in the LCD. Push the right arrow five times, to reach the B window status screen. This will show the cpm for thoron. You may also listen to the beeps, which have a different pitch for different windows. Thoron has a high-pitched beep.

Floor/wall, wall/wall and split-level seams are common locations for radon entry points. So are sumps, wells, beam pockets and utility conduits, entering the building from below ground level. It is useful, before starting the sweep, to have a sketch map of the area, with the likely culprits marked, on which to write down the readings. While making this sketch map, the RAD7 can be taking a benchmark radon measurement in the center of the room. Take at least four 5-minute-cycle readings. Later radon readings, at likely entry points, can then be compared with this benchmark.

To start the sweep, hold the small drying tube as a wand, with the open end either in, or as close as possible to, the most likely radon entry point. Keep it there for at least five minutes. If the thoron count, in window B, during this time, exceeds 2 cpm, say, then you know a) that you were right in your suspicion, and that you are, indeed, close to a radon entry point, and b) that thoron is present in the soil gas, so you can concentrate on thoron for the rest of the survey. Move the wand a foot or so in any direction to see if the window B cpm changes appreciably, in the next cycle.

If there are few or no counts in window B, then either the location is not a radon entry point, or there is no appreciable thoron in the soil gas. You must, then, keep the wand in that position for another 10 minutes, or until the counts in window A start to rise rapidly. If, after fifteen minutes, there are still only a few counts in window A, and the radon concentration, displayed at the end of the third 5-minute cycle, is still very low, then you can be confident that the position is not a radon entry point. On the other hand, a high radon concentration, without thoron, does not necessarily indicate a radon entry point if the whole basement is high. In either case, you need to note the reading on your sketch map, and move to another likely point to repeat the process, first looking for thoron.

If no thoron is found at any time, then the map of radon concentrations, will help to identify entry points. Once thoron has been detected, the whole search is made much easier. Reset the cycle time to two minutes. Spend one complete cycle at each suspected radon entry point, observing the counts in window B, or listening for the characteristic thoron beeps. You will quickly determine the location and relative strengths of the radon entry points, from the cpm in window B, for the different locations. Note that, in this procedure, you must ignore the counts in window A, because they refer to radon that entered the measurement chamber as much as 10 minutes previous to the observed counts.

Even if thoron is present at some points, there is still a possibility that there may be a radon entry point showing little or no thoron. This could occur if the path taken by the soil gas was very long, or the flow was slow. Conduit for a utility service, or a path up a hidden shaft in a wall, could delay the entry of the soil gas by several minutes. Each minute's delay halves the concentration of thoron.

4.3.6 Drilled Sampling Points

Some mitigators drill a number of test holes through the concrete slab, to sniff the soil gas beneath and to test the communication between different areas of the slab. They then install the suction points of the mitigation system where the sub-slab radon readings are highest. This approach is complementary to the search for actual radon entry points, as described above. Both methods are likely to result in a similar, final configuration of the mitigation system, though locating the entry points can also indicate where additional sealing is required.

4.3.7 Spot Readings

A spot reading may be accepted only as a rough indicator of the radon level at any location. This is not only because a short-term reading is less precise, but also because it does not average out the fluctuations in radon level through a typical day. The EPA protocol calls for a measurement to cover at least two days. Quite often, the indoor radon concentration tends to be higher in the early morning, after a cold night, and lower at the end of a warm day.

Furthermore, the radon concentration, typically, takes hours to recover from open doors and windows so, unless the house was closed up tight for many hours beforehand, the spot-reading radon level will be significantly lower than an average, taken over several days, in closed house conditions.

For this spot reading, the sampling point should be away from walls and floor. Thoron is not an issue in this measurement, so the larger, laboratory drying unit may be used, instead of a small drying tube. The cycle time may be left at five minutes. At least four, better six, cycles should be taken, of which the first two should be ignored. Alternatively, increase the cycle time to 10 minutes, or more, and ignore the first reading.

To measure a radon level of 4 pCi/L, with a standard deviation of no more than 10%, needs a run of one hour (six cycles of ten minutes, say).

4.4 Grab Sampling

4.4.1 Applicability

The ability of the RAD7 to "grab" a collected sample is useful when it is not possible to take the RAD7 to the location to be tested, or when the RAD7 is pre-occupied with continuous monitoring and will not be available until later. The Grab functionality is also useful when many samples must be gathered from different rooms of a building within a short timeframe.

However, if the RAD7 is available and can be taken to the test location, then data quality is much improved by a) monitoring the radon level over an extended period of time, such as 1-day, or, if that is not a possibility, b) making a short-term measurement such as described in Chapter 4.2.10, or else just sniffing for a spot reading, as described above.

Grab samples have the same shortcomings as spot readings. The radon concentration 'grabbed' is unlikely to be representative of the EPA average level at the location of the sample. The precision of the reading is also limited by the short time for counting.

4.4.2 Preparation

It is important that the RAD7 be well dried out prior to accepting the grab sample. First, purge the unit with fresh, dry air for five minutes. Then connect the laboratory drying unit in a closed loop with the RAD7 so that air from the outlet passes through the desiccant and back into the inlet. Note that air should always flow the same way through the desiccant. Purge for ten minutes then check the relative humidity (push [MENU] [ENTER] [ENTER], then [➔] [➔]). If the RH is not below 8%, repeat the process. Keep the pump running until ready to take the grab sample.

4.4.3 Protocol

Choose the Setup, Protocol, Grab menu selection, and push [ENTER]. This will set up all the measurement parameters correctly. For the printout, choose Setup, Format, Short.

4.4.4 Taking the Sample

If the RAD7 is at the location, simply start the test ([MENU] [ENTER] [➔] [ENTER]).

Alternatively, samples may be taken in tedlar air sampling bags. Samples of at least five liters are required.. Any sampling pump may be used. Even the RAD7 could be used as a sampling pump, but remember to purge the instrument of old air first.

These bagged samples may be connected to the RAD7 and analyzed later. Make sure there is active desiccant and the inlet filter in place, between the sample bag and the RAD7.

4.4.5 Analysis

With the grab sample source connected to the RAD7, start the test ([MENU] [ENTER] [➔] [ENTER]). The pump will run for five minutes, flushing the measurement chamber, and then stop. The RAD7 will wait for five more minutes, and then count for four 5-minute cycles. At the end of the run, the RAD7 will print out a summary, including the average radon concentration, a bar chart of the four cycles counted, and a cumulative spectrum. The measurement process takes 30 minutes.

If the analysis is made more than an hour after the sample was taken, a correction must be applied for the decay of radon in the sample.

4.5 Thoron Measurement

4.5.1 Thoron and Radon

Thoron is an isotope of the element radon having an atomic mass of 220, so it is also known as radon-220. The word "radon" without a mass number almost always refers to radon-222. Thoron and radon have very similar properties. They are both chemically inert radioactive gases that occur naturally from the decay of radioactive elements in soils and minerals. Both thoron and radon are members of decay chains, or long sequences of radioactive decay.

While radon results from the decay of natural uranium, thoron results from the decay of natural thorium. Both uranium and thorium are commonly found in soils and minerals, sometimes separately, sometimes together. The radioactive gases radon and thoron that are produced in these soils and minerals can diffuse out of the material and travel long distances before they themselves decay. Both radon and thoron decay into radioactive decay products, or progeny, of polonium, lead, and bismuth before finally reaching stable forms as lead.

Thoron and radon and their respective progeny differ very significantly in their half-lives and in the energies of their radiations. While radon has a half-life of nearly 4 days, thoron has a half-life of only 55 seconds. Since thoron is so short lived, it cannot travel as far from its source as radon can before it decays. It is commonly observed that compared to that of radon gas, a much smaller fraction of the thoron gas in soil ever reaches the interior of a building. Even so, thoron can still be a hazard since its progeny include lead-212 which has a half-life of 10.6 hours, more than long enough to accumulate to significant levels in breathable air.

4.5.2 Thoron Measurement Issues

Many difficulties impede the accurate measurement of thoron gas. The presence of radon gas (often found together with thoron) can interfere with a measurement. The short half-life of thoron gas makes some aspects of the measurement easier, but makes sampling method a critical issue. Thoron concentration can vary greatly through a space, depending on the speed and direction of air movement as well as turbulence. The position of the sample intake can strongly affect the results.

For many instruments, radon and thoron interfere with each other. Generally speaking, it is difficult to measure one isotope accurately in the presence of the other. But compared to other instruments, the RAD7 is much less susceptible to radon-thoron interference due to its ability to distinguish the isotopes by their unique alpha particle energies. The RAD7 separates radon and thoron signals and counts the two isotopes at the same time with little interference from one to the other.

Some issues of concern in measuring radon do not apply to thoron. The short half-lives of thoron (55 seconds) and its first decay product (Po-216 - 0.15 seconds) mean that thoron measurements can be made quickly and in rapid succession, since there is little concern with growth and decay delays. The RAD7 responds virtually instantly to the presence of thoron; its time constant for response to thoron is less than 1 minute. The chief limit on the thoron response speed is the pump's ability to fill the internal cell. And the RAD7 clears just as rapidly when you purge the instrument with thoron-free air. In fact, you need not purge the instrument at all as thoron's short half-life ensures that it will be gone in a few minutes.

In thoron measurement the sample pump must run in a continuous fashion, at a steady consistent flow rate. If the flow rate of the sampling pump changes, then the RAD7 thoron result will also change. Flow rate affects the amount of thoron in the internal cell, since a significant fraction of the thoron decays in the sample intake system as well as within the instrument. For the most accurate thoron measurements we recommend that you use a consistent sample intake system (always use the same hose and filter arrangement) and pay special attention to air flow rate. Be sure the filters, hoses, and RAD7 inlet and outlet ports remain free from obstruction. Use a flow meter (rotameter or "floating ball" type) to check that the flow remains consistent. Note that the flow rate affects the thoron reading, but not radon due to its much longer half-life.

The RAD7 measures thoron concentration in the air at the point of sample intake. Since thoron varies from place to place depending on the motion of the air, the instrument operator may find it necessary to make measurements in several locations to properly assess a thoron situation. Fortunately, rapid-fire thoron measurements are very easy to do with the RAD7.

4.5.3 Calculation and Interference Correction

The RAD7 calculates thoron concentration on the basis of the count rate in spectrum window B which is centered on the 6.78 MeV alpha line of Po-216, the first decay product of thoron gas. To further avoid interference from radon, the RAD7 applies a correction to the thoron count rate to compensate for a small percentage of "spillover" from window C.

If the spill from window C to window B is too great relative to the base amount in window B, it becomes impossible to calculate thoron concentrations with sufficient certainty. This situation can be avoided by purging the RAD7 with fresh air and waiting with the unit turned off for two hours prior to testing for thoron. This provides enough time for the peak in window C to decay to one tenth of its original value.

As of firmware version 2.5, the RAD7 calculates radon concentration from the count rate in window A (SNIFF mode) or windows A plus C (NORMAL mode). The RAD7 compensates for interference from the long-lived progeny of thoron (10.6 hours) by applying a correction to the radon count rate in both SNIFF and NORMAL modes. The correction is based on a fixed fraction of the count rate in the D window (around the 8.78 MeV peak of Po-212) which predicts the amount of thoron progeny activity in the A window (due to the 6.05 and 6.09 MeV peaks of Bi-212). Note that the uncertainty figures given with each reading include the effect of these corrections.

4.5.4 Avoiding Longer Lived Decay Products

Although the RAD7 now corrects for the buildup of the long-lived thoron progeny (10.6 hour), we recommend that you avoid unnecessary exposure of the instrument to high levels of thoron for long periods of time. The presence of these long-lived progeny can make low level radon measurements somewhat less accurate than would otherwise be possible. But if you err, the 10.6 hour half-life of the thoron progeny makes for a temporary inconvenience of a few days at worst.

4.5.5 Decay Correction, Flow Rate, and Thoron Calibration

As discussed above, thoron's rapid decay causes the intake path and the air flow rate to become important factors in calibration. The RAD7 factory calibration for thoron is based on a standard RAD7 inlet filter, a standard 3-foot long, 3/16 inch inner diameter vinyl hose, and a standard small (6 inch) drying tube. Deviation from this arrangement can change your thoron results. For example, if you were to use a very long hose for thoron sampling, then the sample might decay significantly before it ever reached the instrument inlet. The same thing might happen if you substituted the small drying tube with the large drying column. If you were to use a non-recommended inlet filter, the flow might be restricted enough to greatly lower the result.

4.5.6 Calculating Sample Decay

The thoron concentration at the inlet of the RAD7, C1, can be expressed mathematically as

C1 = C0 * exp(-L * V1 / q)

where C0 is the original sample concentration, V1 is the volume of the sample tube + drying tube + filter (around 50 mL), q is the flow rate (around 650 mL/min), and L is the decay constant for thoron (.756 /min). A typical value for C1/C0 is then

C1/C0 = exp(-.756 * 50 / 650) = .943 = 94.3%

This is the number DURRIDGE assumes in the factory calibration. Adding a few extra feet of hose will not matter much (about 0.5% per foot), but if we were to use a 100 foot hose instead (V1 is around 580 mL) then the same calculation would give .509 or 50.9%, a significant reduction from 94.3%!

4.5.7 Calculating Internal Cell Concentration

The sample decays slightly in going from the RAD7 inlet to the internal cell, due to internal hose and filter volumes. This decay can be calculated in a similar fashion to the above, giving the internal cell inlet concentration, C2, about 95.5% of C1. Within the RAD7 internal cell, the equilibrium thoron concentration, C3, will be determined by the following formula:

C3 = C2 / (1 + L * V2 / q)

where L and q are as above, and V2 is the volume of the internal cell (around 750 mL). Typical values then give C3/C2 as

C3/C2 = 1/(1+.756 * 750/650) = .534 = 53.4%

Multiplying this result by the sample decay factors calculated above, we obtain an overall concentration in the internal cell of 48.1% of the original sample. Recognizing the uncertainty of several of the inputs to these formulas, particularly the flow rate, we will round the overall result to 50%.

4.5.8 Internal Cell Thoron Sensitivity Calibration

Preliminary investigations have shown that the RAD7's internal cell thoron sensitivity in cpm/(pCi/L) is identical to its radon SNIFF mode sensitivity, to within 25%. We have no reason to expect any sizable difference between the thoron and radon SNIFF mode sensitivity values, so we are presently assuming that the two values are indeed nearly equal, and claim an uncalibrated thoron precision of +/- 30%.

With calibration against a thoron standard assessed by gamma spectrometry we are able to state the thoron sensitivity with much higher certainty. This thoron calibration is offered as an option and for this we claim an overall accuracy of +/- 20%. Otherwise we estimate the overall thoron sensitivity to be 50% of the radon Sniff sensitivity to account for sample decay in the intake and internal cell. The RAD7 has a typical radon Sniff sensitivity of .25 cpm/(pCi/L), so we estimate the typical thoron sensitivity to be around .125 cpm/(pCi/L).

4.5.9 Setting up a Thoron Measurement

Sniffing for thoron is much the same as sniffing for radon, except it tends to be a little faster. If you are just "prospecting", you probably will not be very interested in getting the most accurate results possible, so technique is not critical. But if you are trying to make an accurate measurement, technique is of great importance.

For accurate thoron measurement, always use the same sample taking arrangement. Keep the sample tubing short: no more than 6 feet (2 meters) total length. Use one of the small drying tubes supplied with the instrument, positioned vertically and filled with fresh (blue) desiccant. Always use an inlet filter, free from flow restrictions or clogs. Avoid obstructing the intake of the sample tube. The recommended configuration is pictured below. For the most accurate results, check the flow rate with a flow gauge to be sure it is consistent from measurement to measurement. Use the RAD7's Setup Protocol command to choose Thoron protocol for a 5 minute repeating cycle. Be sure the instrument has been "dried out" before making a measurement. Position the sample tube intake and start the test.

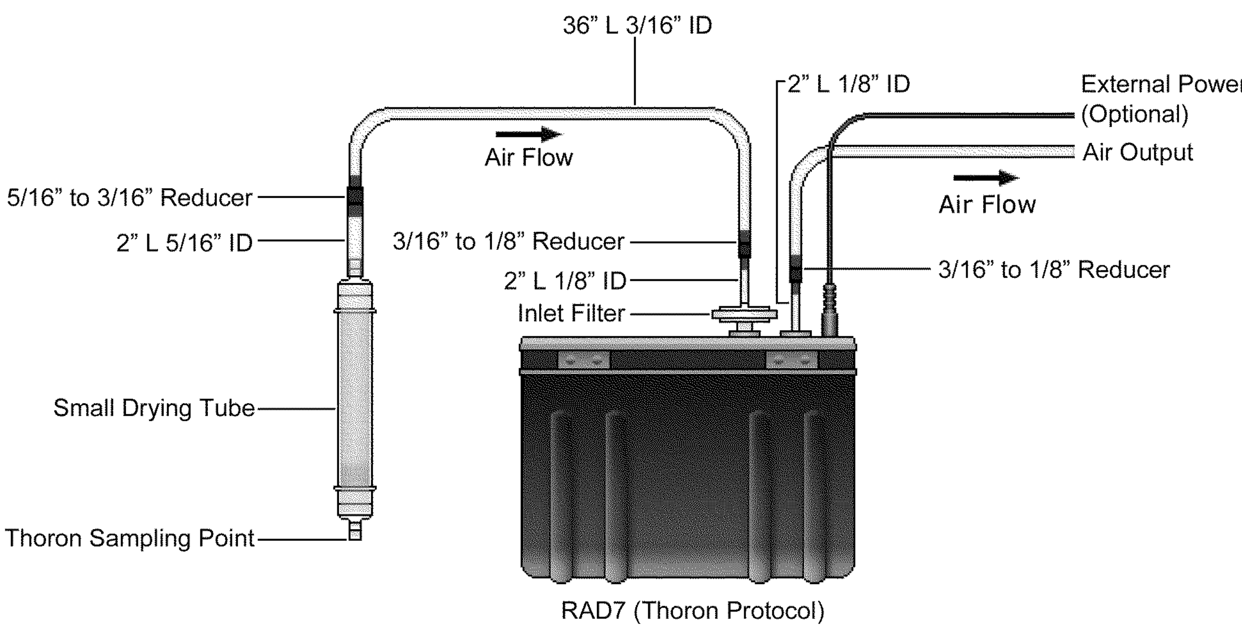
4.5.10 Thoron Mode

Thoron mode causes the RAD7 to print both thoron and radon concentrations (in pCi/L or Bq/m3) in continuous data logging or in subsequent printing of data. Thoron mode also directs the automatic pump setting to continuous pump operation to assure a fresh sample.

The setup parameter "Setup Thoron" allows you to select Thoron mode On/Off, for configuring a particular test to perform thoron readings.

The protocol "Protocol: Thoron" provides a standard test for sniffing both radon and thoron in 5 minute cycles.

Recommended RAD7 Thoron Configuration



4.6 Managing Background

A major concern in radon testing is background. The RAD7 has a number of features that help to keep short and long-term background under control. These are discussed in Chapter 3.11. Following a few simple rules will help to keep background to a minimum.

Short term background is activity left in the detector after the air sample has been flushed from the measurement chamber. The higher the radon concentration and the longer the sample is held in the cell, the more daughter activity it leaves behind. So, to avoid background, when you see high radon readings, finish your measurement, and purge the sample cell promptly. Take the instrument somewhere with little radon, such as outdoors. Make sure the drying tube is connected, and select `>Test Purge`. Let the RAD7 purge for 5 to 10 minutes, or longer if the sample was exceptionally "hot".

The two alpha peaks decay at different rates. The polonium-218 peak, in window A, decays with a 3.05 minute half-life. So in 10 minutes it will be down to about one-tenth of its original count rate. The peak in window C, however, will take over two hours to get down to one-tenth its count rate.

Rather than wait around for hours, you can start the next radon test in SNIFF mode, which ignores window C. In fact, the preset, one and two-day, monitoring protocols, in the RAD7, use AUTO mode, which starts a measurement in SNIFF mode and automatically changes to NORMAL mode after three hours. This takes care of all but extreme exposure to very high radon.

You can always measure the short-term background, with 5-minute SNIFF mode tests. Run a few to see that the background is low.

4.7 Harsh and Hazardous Environments

4.7.1 Splashing Water

Extra care should be taken to prevent water from splashing onto the RAD7 face plate or entering the instrument through the RAD7 inlet. Either situation can cause malfunctions and corrosion. If the RAD7 is to be operated in a harsh environment, such as a cave or mine, where water may splash around, the RAD7 may be protected in two ways:

a) A thin plastic film may be stretched over the face plate and down the sides of the case. It can be pushed down around the hose connectors and plugs can be pushed into data and power sockets, pushing the plastic film down around the pins. The result is to make the instrument almost waterproof.

b)The RAD7 can be enclosed in a large transparent plastic bag with the opening gathered, and held with an elastic band, around the incoming air-sample tubing.

c) The dry air from the RAD7 outlet may be exhausted to the interior of the bag, so ensuring that the RAD7 is operating in a clean and dry environment.

If water ever enters the RAD7, immediate steps should be taken to minimize the impact on the instrument. For detailed instruction see Section 8.4, Water Catastrophe.

4.7.2 Dusty Environment

Dust may contaminate the desiccant and cause elevated radon background due to radon emitted by trace amounts of radium deposited in the desiccant by the contaminating dust. To prevent this, a dust filter should be attached to the tubing at the sampling point, upstream of everything.

A suitable dust filter is supplied with every RAD7. The filter should be replaced when it becomes soiled. Replacements may be purchased from a car-parts supplier as 1960's VW Beetle in-line gasoline filters, part number 803-201-511C, or FRAM G4164, or from DURRIDGE Company.

Please note that any restriction to air flow, including a plugged dust filter, upstream of a passive DRYSTIK will reduce the effectiveness of the DRYSTIK. In a dusty environment, with a dust filter in place, an Active DRYSTIK will continue to work well even if the dust filter becomes partially blocked.

4.7.3 Radiation Hazard

If the RAD7 is to be placed in a position hazardous to the health of individuals, remote communication may be established either through the a wireless network or over telephone lines. Please see Chapter 6 and the CAPTURE user's manual for details.

5. USING *RAD7* ACCESSORIES: TESTING FOR RADON IN THE GROUND AND WATER

5.1 Introduction

With the addition of various accessories offered by DURRIDGE, the RAD7 can acquire the ability to detect radon in water samples, flowing water, soil gas, hard and soft surfaces, and collected objects. These applications and the accessories required for each are described below.

The accessories discussed here are not included with the RAD7. For full details on the usage of a given accessory, please see its user manual. All product manuals are available in print form, and on the DURRIDGE website (www.durridge.com) in PDF format.

The RAD H_2O Accessory

5.2 Radon in Water

5.2.1 The RAD H_2O Accessory

The RAD H_2O is an accessory for the RAD7 that enables you to measure collected water samples to detect radon with high accuracy over a wide range of concentrations, obtaining your reading within an hour of taking the sample. It is particularly suited for well water testing, where immediate results are often required.

The RAD H_2O uses a standard, pre-calibrated degassing system and pre-set protocols, built into the RAD7, which give a direct reading of the radon concentration in the water sample itself. The method is in fact a special variation of the grab sampling method described in the previous chapter.

The most widely supported sample sizes are 40mL and 250mL, as these correspond to the RAD7's built-in Wat-40 and Wat250 protocols. Large water samples of up to 2.5L may be sampled using the Big Bottle RAD H_2O System, with radon concentrations being calculated using the provided CAPTURE software for Windows and Mac OS X.

The RAD H_2O comes with a detailed manual, to which you are referred for further information.

The RAD AQUA Accessory

5.2.2 The RAD AQUA Accessory

The RAD AQUA accessory handles the continuous monitoring of radon in water, offering accurate results in as little as half an hour. Applications for the RAD AQUA include testing water from running faucets and water being pumped from the bottom of a lake. In addition to its rapid response time, the RAD AQUA offers a high degree of sensitivity.

The RAD AQUA functions by bringing air into equilibrium with water passing through an exchanger in a closed loop. During this process, the RAD7 is set to operate in continuous mode, as described in Chapter 4.2.

Since the equilibrium ratio of radon in air to radon in water is affected by temperature, a temperature probe is used to collect water temperature data, and DURRIDGE CAPTURE software for Windows and Mac OS X later accesses the RAD7 data and the water temperature data and calculates the final radon in water readings.

Users are encouraged to refer to the RAD AQUA manual for further details.

5.2.3 The WATER PROBE Accessory

The Water Probe is used to collect radon samples from large bodies of water. The probe consists of a semi-permeable membrane tube mounted on an open wire frame. The tube is placed in a closed loop with the RAD7.

When the probe is lowered into water, radon passes through the membrane until the radon concentration of the air in the loop is in equilibrium with that of the water. As with the RAD AQUA, the RAD7 data and water temperature data are collected simultaneously and accessed by CAPTURE to determine the final result.

As compared to the RAD AQUA, the Water Probe takes longer to make a spot measurement. However it does not require a pump, so power requirements are reduced.

5.3 Soil Gas Sampling

5.3.1 Application

The radon concentration in the soil gas surrounding a house is one of many parameters that impact radon health risk. The construction of the house, the porosity of the soil, the height of the water table, and several other factors are all important. Even if there is no radon in the surrounding soil, the house may still be at risk if it has a well in the basement, or is built on rock, over a fissure. Regardless, it is often of interest to determine the radon concentration in soil gas.

Thoron is usually associated with radon in the soil. When measuring soil gas, it is therefore particularly useful to determine the thoron content as well as the radon content. Should there be significant thoron, it may be used as a tracer, to find radon entry points inside the house. See Chapter 4.3.2 for details.

5.3.2 The Soil Gas Probe Accessory

The cost and complexity of a soil gas probe increases with the depth to which it can be inserted. A variety of probes are available from DURRIDGE, the simplest of which will penetrate to a depth of 3 feet.

5.3.3 Soil Gas Probe Preparation

For full details on using a soil gas probe, please refer to the appropriate user's manual found at the DURRIDGE website (www.durridge.com). The basic procedure can be summarized as follows.

Insert the soil probe. Make sure that there is a reasonable seal between the probe shaft and the surrounding soil, so that ambient air does not descend around the probe and dilute the soil gas sample.

Between the probe and the RAD7, connect the included water trap (which could be just a jar with two air-tight hose connectors in the lid). Then connect the laboratory drying unit, and the inlet filter. A water trap is included in the package when the DURRIDGE soil gas probe is purchased.

Set the protocol to Sniff. Soil gas is normally so high in radon that it is not necessary to use long cycle times to gain precision. Five minute cycle times are sufficient.

5.3.4 Running the Test

Start the test. (Test, Start, [ENTER]). On the LCD screen you will see the first status window. Push the right arrow twice and the screen will display the temperature, relative humidity, battery voltage and pump current. Pay particular attention to the relative humidity and pump current. The humidity should gradually drop down to below 10%, and stay there.

If the pump current starts to rise much above 100 mA, it suggests that the soil is not porous, in which case it may be that a good soil gas sample cannot be drawn, no matter how powerful the pump is. With the RAD7 pump current above 100 mA, the air flow rate will be significantly reduced from the nominal 1L/min. This will not affect the radon reading, but will reduce the effective sensitivity to thoron, as more of the thoron will decay en route to the RAD7. If desired, an additional pump may be used, but it should be placed upstream of the RAD7, so that the RAD7 is operating at normal pressure. In fact, with an external sampling pump in use, the RAD7 pump can even be switched off altogether.

5.3.5 Interpreting the Data

As with any Sniff test, the first two 5-minute cycles should be ignored. The next one or two cycles should be averaged, to arrive at the radon concentration of the soil gas.

For thoron, some estimate has to be made of the time taken for the sample, after it has left the soil, to reach the RAD7. This requires an estimate of the volume of the sample path, including the probe, water trap, tubing and drying unit, and an estimate, or measurement, of the flow rate. For example, if the total volume of the sample path is 2L, and the flow rate is 0.5 L/min, then the sample delay is about 4 minutes. If the thoron decays by half every minute, then after four minutes the concentration will be just 1/16th of the concentration in the ground. So, the thoron concentration measured by the RAD7 would be multiplied by 16.

5.4 Emission Measurements

5.4.1 Application

With its internal pump, sealed sample path, and inlet and outlet connectors, the RAD7 is well suited to the measurement of radon emissions from objects and surfaces. Furthermore, the ability to count only the polonium-218 decays means that dynamic measurements are clean, and not complicated by long-half-life events.

5.4.2 Open or Closed Loop Configurations

Emissions may be sampled from collected objects using DURRIDGE's Bulk Emission Chamber. It is also possible to analyze emissions from soft or hard surfaces, with the aid of a DURRIDGE Surface Emission Chamber, which consists of a plate-like enclosure capable of forming a tight seal around the surface in question. In both cases, the RAD7 draws air from within the enclosed space, through the desiccant and inlet filter, and into the measurement chamber. The air may then be returned to the enclosure from the RAD7 outlet, to form a closed loop. Alternatively, in an open loop configuration the air being drawn from the enclosure may be replaced with 'zero' air from a cylinder, or with ambient air, which should have a low but known radon concentration.

With the closed-loop configuration, the system is first purged. Then once it has been sealed, the radon concentration within the loop is monitored in SNIFF mode, with short, e.g. 15 min., cycle times, for a few hours. It is necessary to know the total volume of the closed-loop system. For this purpose, the volume inside the RAD7 may be taken as 1L. The initial rate of increase in radon concentration (neglecting the first 15-min cycle), multiplied by the volume, gives the rate of emission of radon. A reduction in the slope, as the radon level builds up, may be due to leaks in the system, or to a reduction in the net emission.

With the open loop configuration, a steady and known flow rate must be established. If a cylinder of 'zero' air, or nitrogen, is used, then the RAD7 internal pump may be set to Off, and a pressure reduction valve may be used to control the flow rate. With ambient air, the internal pump may be set to On, for a continuos flow. In both cases, a flow meter is required.

A steady state should be achieved and a long-term measurement may be made. The rate of emission will equal the radon concentration times the flow rate. The precision will depend on the concentration and the duration of the measurement.

The Bulk Emission Chamber

5.4.3 Bulk Emissions

The DURRIDGE Bulk Emission Chamber is an airtight box with two well separated hose connectors. The material to be tested is placed in the chamber, which is then connected to the laboratory drying unit, and thence to the inlet filter on the RAD7. The other box connector has tubing attached, which is either connected to the RAD7 outlet for closed-loop operation, or to a cylinder of zero gas or ambient air.

Note that bulk emissions are affected by pressure fluctuations and by temperature and humidity. All these parameters can and should be controlled in both the closed-loop and open-loop configurations. Radon emission is also dependent on the grain size of loose materials, and the porosity of any bulk material.

In addition to radon, thoron can also be measured in the Bulk Emission Chamber. In the open loop mode, a correction is required for the decay of the thoron during the time between its emission and measurement in the RAD7. In closed loop mode, another correction must be made for the portion of thoron that gets fed back to the enclosure. Note that for thoron, both the closed loop and open loop modes are steady-state measurements.

The Surface Emission Chamber

5.4.4 Surface Emission

DURRIDGE offers two surface emission chambers, one for solid hard surfaces, and another for soft soil surfaces. Each consists of an circular plate which is sealed against the surface under investigation. The Solid Surface Emission Chamber accomplishes this using a rubber seal, while the Soil Surface Emission Chamber uses a penetrating metal rim.

The measurement procedure is similar to that of the Bulk Emission Chamber described above. Once the total emission rate within the enclosure has been calculated, it may be divided by the area of the surface within the sealed boundary, to determine the emission per unit area.

5.5 Supporting Accessories

5.5.1 Overview

DURRIDGE offers additional RAD7 accessories which improve the accuracy of radon and thoron reporting by optimizing operating conditions.

The RAD7 is able to detect radon in concentrations of up to 20,000 pCi/L (750,000 Bq/m^3). For applications involving higher concentrations of radon, DURRIDGE offers the Range Extender, a device which removes 90% of the radon from the air sample entering the RAD7, giving the instrument the ability to operate in conditions under which it would otherwise be unable to cope. A final concentration figure is attained by multiplying the reported result by ten.

Another limitation of the RAD7 is that it loses reporting accuracy under high humidity conditions. The use of desiccant ensures that the air entering the RAD7 inlet is not too humid, but since desiccant is expended quickly when exposed to very moist air, DURRIDGE offers the DRYSTIK, an instrument which removes moisture from the air entering the RAD7 without removing the radon itself. The premium DRYSTIK model is capable of reducing the humidity of a typical air sample to 4% in under 20 minutes, greatly prolonging the life of the desiccant, or eliminating the need for it altogether.

The Range Extender and DRYSTIK are described in more detail below. For full documentation on each, please refer to the Range Extender and DRYSTIK user manuals, available in PDF format at the DURRIDGE Website (www.durridge.com).

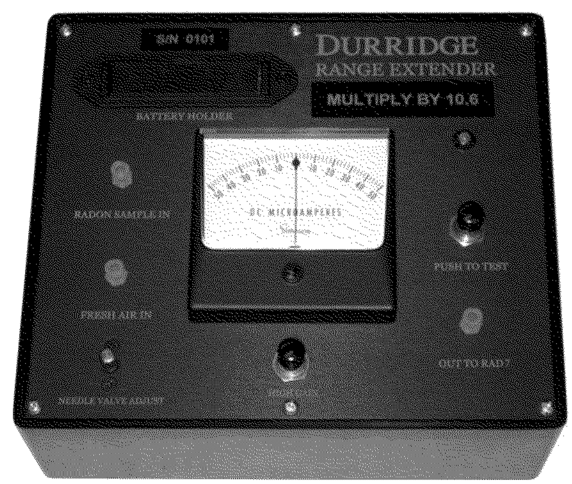
5.5.2 The Range Extender

The Range Extender mixes fresh air with the air being sampled, reducing the concentration of radon entering the RAD7 by a factor of ten. This greatly increases the instrument's effective range.

The Range Extender consists of two parallel capillary tubes joined at one end to an outlet hose connector. Fresh air is fed to the input of one tube while the incident radon sample is fed to the other. A differential pressure sensor across the two tube inputs, with a needle valve for adjustment, is used to ensure that both capillary tubes have the same pressure drop across them.

With this system the radon concentration delivered to the RAD7 is reduced by an order of magnitude, regardless of the strength and flow velocity of the RAD7's internal pump. The RAD7 pump can cycle on and off without affecting the reduction factor.

The Range Extender can be used for the measurement of very high radon concentrations in air, in soil gas, and in water. It can also be used with any other instrument that has its own pump, for any gas. If used to extend the range of thoron measurement, care must be taken to assess and correct for the additional decay of the thoron due to sample acquisition delay.



The Range Extender

5.5.3 The DRYSTIK

The DRYSTIK reduces the humidity of the air entering the RAD7 by transferring moisture from the sample about to enter the RAD7 to the air being pumped out of the instrument. As the air enters the desiccant in the drying unit (which is not included with the DRYSTIK) on its way to the RAD7, it will have already lost most of its moisture, greatly extending the life of the desiccant in the drying unit. In certain cases the need for desiccant is eliminated altogether.

The DRYSTIK has at its heart a Nafion humidity exchanger with diaphragm pump, fixed and variable flow limiters, and a built-in Duty Cycle Controller. These are all contained in a compact, portable enclosure. The DRYSTIK's pump compresses the sample air inside the membrane tubing, initiating the transfer of water molecules to the outer purge flow, drying the incoming air as it moves through the device.

The DRYSTIK is available in three variants, based on the length of Nafion tubing used. The premium 144-ADS model is capable of bringing the relative humidity of air flowing at 0.15 L/min down below 10% in less than four hours, and maintaining the RH below 6% indefinitely without any desiccant. This allows a RAD7 to operate under optimum conditions with the highest sensitivity and lowest operating cost. At a higher flow rate of 1.2 L/min, the DRYSTIK can bring the RH down below 12%, which is sufficient for enhanced-sensitivity thoron measurement.

For soil gas measurement, the DRYSTIK provides a high flow capability, supporting the detection of short-lived thoron. For radon, the ability to lower the flow with the built-in Duty Cycle Controller means that continuous soil gas readings may be made indefinitely, without any risk of fresh air diluting the soil gas sample by diffusing from the surface down to the extraction point. Given its versatility, the DRYSTIK is effective for a wide range of applications.

The DRYSTIK (Model ADS-3R)

6. PC Connectivity

6.1 PC Connectivity Basics

The RAD7's built-in serial port allows you to transfer radon data to your computer and to communicate with the device remotely in real time. DURRIDGE provides a free software utility for Windows and Macintosh OS X, *CAPTURE*, which makes it easy to perform these actions, as well as to monitor the RAD7's status, graph radon and thoron data, apply corrections to account for environmental factors, and export the results for analysis in a spreadsheet program or other software.

It is also possible to use a terminal emulator program to interface with the RAD7, and to write your own RAD7 communications software using the protocol documented later in this chapter.

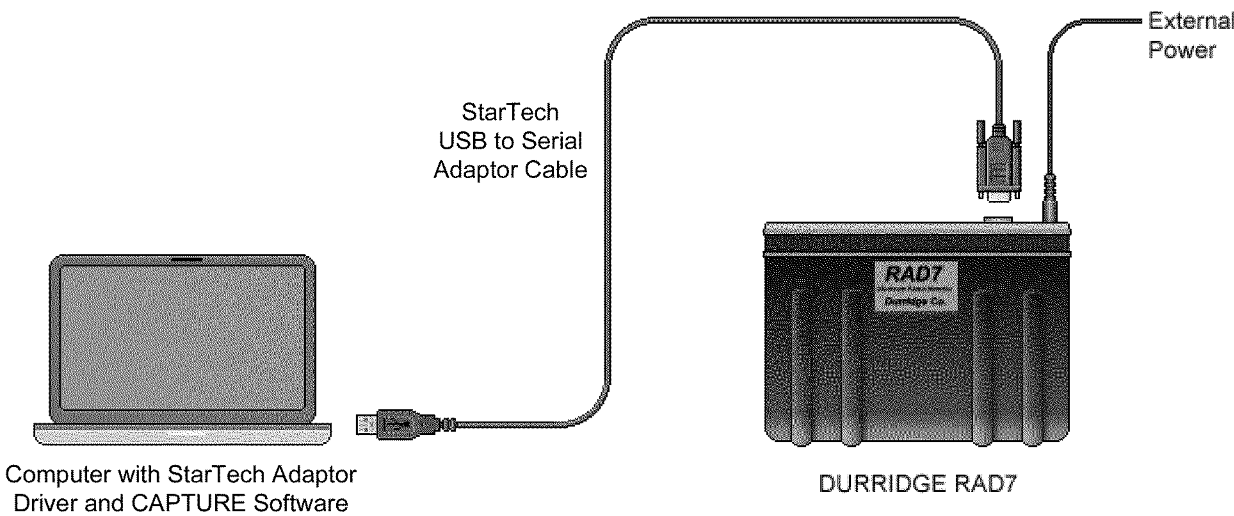
An overview of the CAPTURE software is provided in Section 6.2, and the full program documentation is available at www.durridge.com/capturehelp/. This documentation is also accessible from within the CAPTURE application, using the Help menu.

Following the section on CAPTURE, the remainder of this chapter contains technical information which will be of interest to advanced users who intend to communicate with the RAD7 via a terminal window and those who wish to write their own software for communicating with the RAD7.

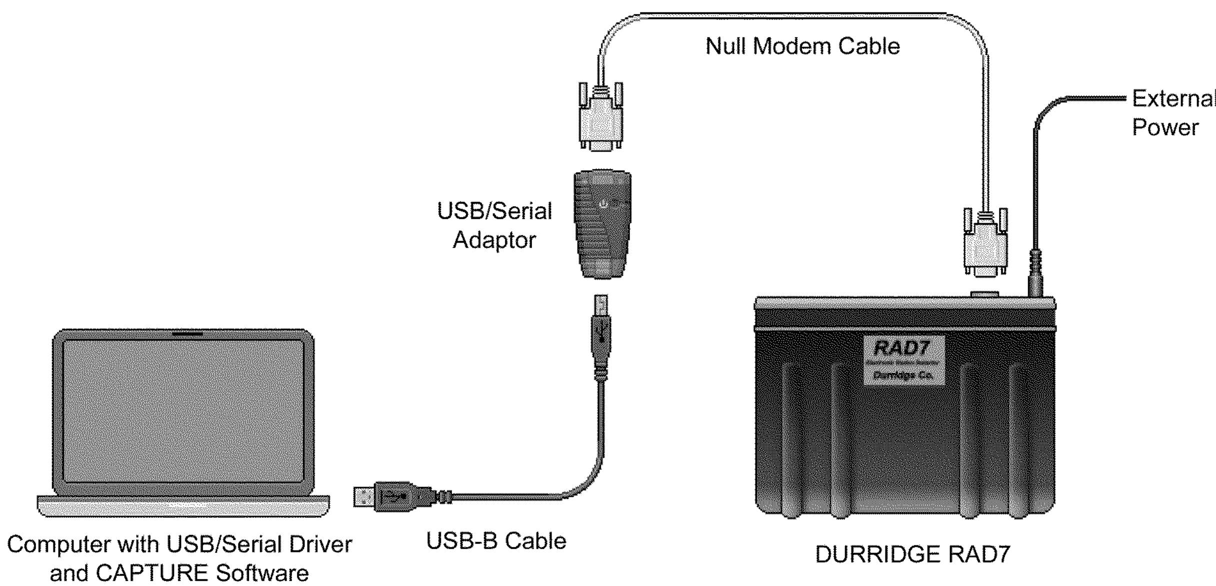
6.1.1 Connecting the RAD7 to the Computer

On most systems the RAD7 should be connected to the computer using the included USB to Serial adaptor, and it will be necessary to install the included adaptor driver software. If your computer has a physical serial port however, it is possible to instead use an RS232 DB9 female to female null modem cable to connect the RAD7 directly to the computer, without the need for adaptors or drivers.

The diagrams on the next page show how to connect the RAD7 to a computer using two different kinds of USB to Serial adaptors: the StarTech adaptor (top), and the Keyspan adaptor (bottom).



Connecting the RAD7 to a computer using the StarTech USB to Serial Adaptor



Connecting the RAD7 to a computer using the KeySpan USB to Serial Adaptor

It is recommended that the RAD7 remain plugged into external power to prevent its battery from dying while it is connected to the computer.

For connecting more than one RAD7 to a computer, it is possible to use several USB to serial adaptors simultaneously, with each plugged into a USB port on the computer (it is not advisable to plug multiple adaptors into a single USB hub.) Alternatively, a multi-port USB to serial adaptor may be purchased.

6.2 CAPTURE Software

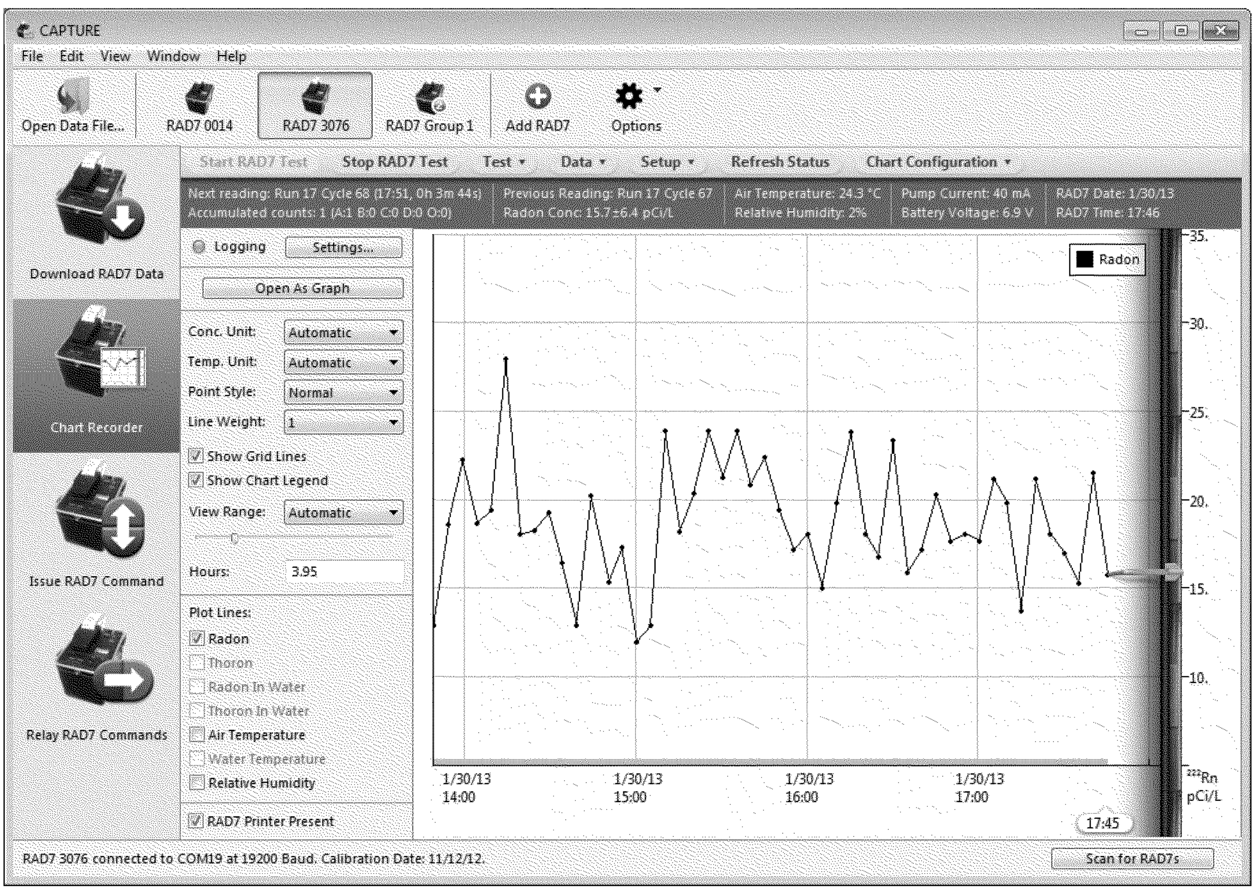
CAPTURE is intended to simplify the transfer of data from the RAD7 to a computer. It also provides a wealth of graphing and data analysis options, and offers the ability to export data to other programs for further review. The software is available for Windows and Macintosh OS X.

This section serves as a brief introduction to the CAPTURE software.

6.2.1 CAPTURE Installation

The latest version of the CAPTURE software may be downloaded from the DURRIDGE website (www.durridge.com/capture). Download the appropriate version of the software for Windows or Mac OS X. In Windows an installer program will install the necessary components and place shortcuts in the Start Menu and on the desktop, if desired. To install CAPTURE for the Macintosh, open the downloaded .dmg disk image file and drag the CAPTURE application into the Applications folder or to the location of your choice.

Next connect the RAD7 to the computer using the provided adaptor cable as described in Section 6.1.



CAPTURE Software running in Windows 7

6.2.2 Feature Summary

CAPTURE's capabilities fall into three main categories: downloading RAD7 data, graphing and analysis, and real-time RAD7 monitoring. An overview of each is described below.

6.2.3 Downloading RAD7 Data

CAPTURE's original and primary function is to download RAD7 data. Once connected to a RAD7, the program can download all of the device's data, or a particular data run. For a more complete record set, supplementary output containing thoron concentration records may also be obtained. When a download operation is complete, the results are saved to disk in the format of the user's choice.

In addition to being able to download data from RAD7s connected directly to the computer, CAPTURE can obtain data from remote RAD7s, connected via a remote desktop software, a local network, or a modem.

6.2.4 Graphing and Analysis

Once RAD7 data has been downloaded and saved to disk, it may be displayed as a graph. CAPTURE's Graph Window allows for the display of radon, thoron, temperature, and humidity data. Navigation controls make it possible to select the data points within a specific date range and zoom in to that region for a closer look.

Accompanying the graph display is a statistics panel showing information about the point nearest to the cursor and the points within the selected region, as well as the points comprising the entire data set.

A synthesized spectrum display appears in another panel, providing an indication of the changes that occur within the RAD7 as a testing session progresses.

RAD7 Profiles based on device calibration data may be applied to graphs to improve the accuracy of the data shown. Data points may also be corrected for temperature, humidity, and other variables. Any problematic data records will be examined by CAPTURE's comprehensive error catching system and reported to the user.

CAPTURE supports the exporting of both raw RAD7 data and more complete error-corrected RAD7 data in a number of formats, for use in spreadsheets and other analysis tools. Summary reports may also be generated, providing general overviews of the collected data.

6.2.5 Real-Time RAD7 Monitoring

CAPTURE is capable of monitoring multiple local and remote RAD7s simultaneously in a Chart Recorder, displaying status details and plotting radon concentrations in real time as they are recorded. A statistics panel is automatically refreshed as new information arrives.

Besides tracking the sate of each connected RAD7, it is also possible to issue menu commands, performing such tasks as starting and stopping tests and setting the protocol. All of the functionality of the RAD7's physical controls are accessible from within CAPTURE's graphical interface.

As stated above, it is suggested that users examine the complete CAPTURE documentation, available from the www.durridge.com/ capturehelp/, and from within the program's Help menu.

6.3 RAD7 Communication Protocol

6.3.1 Communication Requirements

Although the CAPTURE software for Windows and OS X provides a complete solution for downloading RAD7 data and issuing RAD7 commands, it may be desirable to communicate with the device using a terminal window, or with custom communication tools designed to fulfill specific needs.

The RADLINK firmware, installed standard with every RAD7 sold, enables the RAD7 to respond to commands issued through its serial port. With RADLINK installed, all of the commands available through the RAD7 keypad will also be available via the serial port. From a computer you may, for example, change the RAD7's operating parameters, complete a test, and then download the accumulated data.

6.3.2 RAD7 Command Format

The format of commands issued to the RAD7 serial port match, as closely as possible, the format of the commands available to the user at the RAD7 keypad. For example, the command to change the cycle time to 1 hour is "SETUP CYCLE 01:00". The command to turn off the audio beeper is "SETUP TONE OFF". The command to send over the data from run number 3 in comma-delimited form is "DATA COM 3". (This particular command is described further in Chapter 6.3.3, Parsing RAD7 Data.)

Besides the ordinary RAD7 commands, additional commands have been implemented via RADLINK which add functionality and in some cases substitute for other commands. These commands all start with the word "SPECIAL". One such command is "SPECIAL STATUS", which gives information about the current status of the instrument. It is like "TEST STATUS", but does not continue to update the information every second; instead, it returns control to the user.

The third standard ASCII character, ETX, functions as a remote "menu" key that can be used to interrupt certain RAD7 activities and prepare it to accept a new command. The RAD7 replies with a prompt, the greater-than character ">", that tells you it is ready for a new command. When using a terminal emulator program, you will always type commands at the prompt.

All commands must be followed by a carriage return (the thirteenth standard ASCII character), denoted here as <CR>. No command will be activated until the <CR> goes through. Once you have typed a command, always end with a carriage return keystroke. This key may be marked "Enter" or "Return" on your keyboard.

If the RAD7 cannot understand your command, for example if you typed words in the wrong order or misspelled something, it will respond with

?ERROR

followed by a list of acceptable command words.

The case of the command does not matter, nor does the numeric format of numbers. In the last example, "data com 03", "Data Com 3", and "dAtA coM 03.00" all work equally well.

6.3.3 Parsing RAD7 Data

Stored RAD7 data can be obtained through the "Data Com ##" command. Specify the run number in the command line and finish with a carriage return. Alternatively, issue the "Special ComAll" command to download all runs from the RAD7.

Each cycle produces a record containing 23 fields. Carriage-return line-feeds separate the records, and within each record, commas separate the fields. Fields may have leading zeros, extra space characters, trailing decimals, etc., which may need to be trimmed. When the RAD7 responds to a Data Com or Special ComAll command, each line returned represents a different cycle. Here is an example of a single line:

```
009,99,10,29,04,18,4823.,337.8,45.4,
2.9,46.6,0.3, 2201,14, 23.7, 5, 7,
7.09, 00, 125, 28.32743, .8500846,
255<CRLF>
```

The meaning of each of these values is described in the table on the next page.

RAD7 Data Record Content:

ID	Field Name	Notes
1	Record Number	Ranges from 001 to 999
2	Year	2 digit value
3	Month	2 digit value
4	Day	2 digit value
5	Hour	2 digit value
6	Minute	2 digit value
7	Total Counts	Integer indicating total counts recorded during test
8	Live Time	Expressed in minutes
9	Percent of total counts in win. A	These 4 windows will not always add up to 100% since counts can come into channels below or above these windows.
10	Percent of total counts in win. B	
11	Percent of total counts in win. C	
12	Percent of total counts in win. D	
13	High Voltage Level	Ranges from 2200V to 2300V
14	High Voltage Duty Cycle	Ranges from 0-100%; typically 10-20%
15	Temperature	Measured in °C or °F depending on RAD7 setup
16	Relative humidity of sampled air	Should be kept below 10% for most accurate test
17	Leakage Current	Ranges from 0 to 255. Above 20 is cause for concern.
18	Battery Voltage	Below 6.00V is a discharged battery. Does not affect accuracy of test but indicates need for recharge.
19	Pump Current	Ranges from 0-260mA. Typically 40-80mA; Above 100mA possible clogged filter or obstruction.
20	Flags Byte	Bit 0 indicates whether pump is in TIMED mode Bit 1 indicates whether pump ON continuously Bit 2 is not defined Bit 3 indicates whether tone is in GEIGER mode Bit 4 indicates whether beeper is activated Bit 5 indicates if spectrum will print after each test Bit 6 indicates if there are multiple (recycle) tests Bit 7 indicates whether RAD7 is in SNIFF test mode.
21	Radon concentration	Expressed in pCi/l, Bq/m3, cpm, or # counts, depending on the units the RAD7 has been set to use.
22	Radon concentration uncertainty	Two-sigma uncertainty - of concentration in the SAME units as the base radon concentration (not %).
23	Units Byte	Bits 0 and 1 indicate the concentration unit: 00 = counts per minute 01 = number of counts 10 = Bq/m3 11 = pCi/L. Bit 2 through Bit 6 are not defined. Bit 7 indicates the temperature unit (0 = °F, 1 = °C)

6.3.4 Terminal Emulator Tips

If you are using a terminal emulator to interact with the RAD7, you can gain access to additional functionality by making sure the terminal has been set up to give ANSI standard escape codes for the function keys and cursor control keys. Set the terminal for either ANSI, VT-52, or VT-100 mode to get these functions. The function keys F1, F2, F3, and F4 act as a remote RAD7 keypad, corresponding to the RAD7 keys [MENU], [ENTER], [⟵], and [⟶]. The Control-C character also acts as the remote [MENU] key (ETX). The backspace/delete key on your keyboard allows you to correct misspelled commands before the carriage return. If this key does not work, then Control-H may handle the same function.

6.4 Serial Port Specifications

6.4.1 Communication Protocol

The RAD7 serial port follows RS-232C convention for signal levels. Positive voltage (+3V to +15V) indicates logic state 0 (SPACE), while negative voltage (-3V to -15V) indicates logic state 1 (MARK).

The connector pin-out follows the IBM PC convention for the 9 pin serial port. The handshaking lines (DTR, DSR, RTS, and CTS) are not fully implemented, and should be considered non-functional (NF), but X-on/X-off flow control can be used.

RAD7 Serial Port Pin Assignments

Pin	Function	Comment
1	Carrier Detect (CD)	NF
2	Receive Data (RD)	
3	Transmit Data (TD)	
4	Data Terminal Ready (DTR)	NF
5	Signal Ground (SG)	
6	Data Set Ready (DSR)	NF
7	Request To Send (RTS)	NF
8	Clear To Send (CTS)	NF
9	Ring Indicator (RI)	NF

The RAD7 serial port implements two-way communication at 300, 600, 1200, 2400, 4800, 9600, and 19200 bits per second (baud); these speeds are available through the 'Special' commands of the RADLINK remote control package. The default speed is 1200 bps.

RAD7 Communication Parameters

Default Rate	1200 bps
Maximum Rate	19200 bps
Recommended Rate	9600 bps
Data Bits	8 bits
Parity Bit	None
Stop Bits	1 bit

The RADLINK remote control software resides in the RAD7's non-volatile memory (NVRAM), but its presence does not decrease the amount of memory available for storing radon data.

6.4.2 Extending the RS-232 Range

The simple, direct serial port to serial port connection has a range limited to around 50 feet (15 meters) by the RS-232-C standard. Options for extending this range include RS-232 line boosters, current-loop and other types of interface converters, short-haul modems, and leased-line modems.

You may use standard data modems to communicate over the telephone system to one or more remote RAD7 monitors, so that when you want to get some data or start a new run, just "dial up" the instrument of your choice. The modem should be Hayes compatible and should be set to auto-answer.

The CAPTURE user's manual contains a section titled Long Distance Communication, detailing other strategies for communicating with distant RAD7s. These include the transmission of commends via Bluetooth, local area networks, and more.

7. Maintenance

Provided the RAD7 is treated with respect, the only maintenance required by the instrument is its regular recalibration. For this, it should be returned to DURRIDGE Company, who will check the health of the instrument, and who will incorporate the new calibration factors in the instrument firmware.

If the instrument is to be used in a harsh environment, where water and/or mud may be splashed on the face plate, the RAD7 should be put in a box or large transparent plastic bag. The air input may be brought into the container by a plastic tube from the sampling point. The air outlet should be left in the container, so that the RAD7 becomes surrounded by clean and dry air.

7.1 Accessories - Usage and Care

7.1.1 Desiccant

Two sizes of desiccant tubes are supplied. In the NORMAL mode, use the large 2" diameter tube (laboratory drying unit). This unit will last for days under continuous operation at high humidity before it needs regeneration.

When used as a Sniffer, the small desiccant tube is recommended. It will last for several hours before replacement or refilling of the tube is necessary. To regenerate the desiccant, the granules should be removed from the tube and spread evenly in a thin layer on a metal or Pyrex glass tray. Heat at about 200°C (400°F) for at least two hours or until granules turn uniformly blue. Allow the desiccant to cool in a closed, but not airtight, container before refilling the acrylic laboratory drying unit or small drying tube.

How long will the desiccant last? This is a common question, and the following information should be helpful.

7.1.2 Laboratory Drying Unit

The column holds approximately 500 grams of Drierite desiccant. This desiccant can adsorb at least 10% of its weight in water, so the water capacity of the column is at least 50 grams. The RAD7 pump develops a flow rate of about 1 liter per minute. With the RAD7 set for continuous monitoring with timed pump operation, the pump operates 20 to 30% of the time. We will assume an average flow rate of 0.3 liters per minute.

The following table shows the moisture content of air at various conditions of temperature and humidity, and the expected lifetime of a charge of desiccant in the Laboratory Drying Unit.

RH	Deg. C	Deg. F	Column Life Days
30%	20	68	23.1
30%	35	95	9.8
50%	20	68	13.3
50%	25	77	10
90%	10	50	13.7
90%	15	59	10
90%	20	68	7.4
90%	25	77	5.5
90%	30	86	4.2

7.1.3 Small Drying Tube (small tube)

The small drying tubes each contain 30 grams of Drierite desiccant. The water capacity of each tube is 3 grams. We will assume that the RAD7 pump operates continuously, for an average flow rate of 1.0 liter per minute. The table shows the expected lifetime of a small drying tube under various humidity conditions.

RH	Deg. C	Deg. F	Tube Life Hours
30%	20	68	10
30%	35	95	4.2
50%	20	68	5.7
50%	25	77	4.3
90%	10	50	5.9
90%	15	59	4.3
90%	20	68	3.2
90%	25	77	2.4
90%	30	86	1.8

7.1.4 Cascading Drying Tubes

To extend the time before desiccant depletion, you may cascade several drying tubes in series. Two factors limit the number of drying tubes you can use. First, each additional drying tube or column adds a small amount of resistance to the air flow, so the pump will have to work a little harder. But the resistance added by a drying tube is much less than the resistance of the inlet filter, so you should be able to cascade several without severely restricting the air flow. Second, each additional tube adds a time lag between sample intake and instrument response.

For continuous monitoring, a 10- to 20-minute lag may be perfectly acceptable, but for sniffing it may not be. You can conservatively estimate the time lag by taking four times the volume of the drying system and dividing by the average flow rate. Consider a continuous monitor application using a laboratory drying column of volume 0.8 liter with the pump in timed operation, giving an average flow rate of 0.2 liters per minute. Four times the volume divided by the flow rate gives 16 minutes for the estimated lag time. This would be perfectly acceptable for continuous monitoring. For radon sniffing, you will usually use the small drying tubes (volume .032 liter), which create negligible delays of less than a minute, even at low flow rates. You can cascade several small drying tubes without trouble.

Do not cascade drying tubes when sniffing for thoron, since thoron's 56-second half-life necessitates that you keep delays to an absolute minimum. For thoron sniffing, use a single small drying tube, and set the pump for continuous (on) operation. Keep hose length to 6 feet (1.8 meter) or less.

7.1.5 Filters

Inlet filters are supplied that fit the metal inlet fitting (male Luer type). These filters block ultra fine dust particles and all radon daughters from entering the RAD7 test chamber.

The filters are manufactured in various pore sizes by several companies, including Millipore and SRI. We favor pore sizes of 1.0 microns or less; pore sizes as small as 0.4 microns can be used with the RAD7 pump.

The filter should be replaced when it has become noticeably discolored or has clogged enough to impede the flow of air. If you cannot suck air easily through the filter yourself, it's time to change the filter.

When you operate the RAD7 in construction areas or basements, dust can quickly build up in sampling hoses, drying tubes, and inlet filters. This dust will slowly clog the filter, restrict air flow, and create strain on the pump. You will have to replace the inlet filter. To greatly slow the buildup of dust, we recommend that you attach a "prefilter" to the intake of the sampling hose, to prevent coarse dust particles from entering. Then, the inlet filter will remove the ultra-fine dust particles that pass through the prefilter and drying system.

We find that automotive gasoline filters can serve as convenient and inexpensive prefilters. A particular filter, intended for Volkswagens, is a small, disposable, clear-plastic capsule containing a pleated paper filter. This filter effectively removes most dust from the air stream, greatly extending the life of the inlet filter. You can buy this type of filter in almost any auto parts store for around $3.

7.1.6 Batteries

Your RAD7 has enough battery capacity to go for two to three days without any external power source. Electronic circuits control the charging and discharging of the battery, avoiding overcharge or destructive discharge. If you maintain the batteries according to the following directions, you can expect to get two to five years of heavy service from them.

Keep the batteries fully charged as much as possible. Try to recharge promptly after use. The RAD7 batteries charge whenever the unit has DC power. With the power cord plugged in and the RAD7 measuring radon, the batteries will charge slowly. Full recharge takes about 48 hours.

With the power cord plugged in and the RAD7 in fast charge mode (not measuring radon), the batteries will charge more quickly. Full recharge takes about 24 hours. The battery voltage indicator on the display (go to Status Window 1) will reach 7.10 to 7.20V when the batteries are fully charged and the power cord is still plugged in.

If the batteries are deeply discharged, to the threshold of battery damage, an electronic circuit will completely disconnect them to avoid further discharge. The circuit will then not allow battery operation until they are completely recharged. If this occurs, you may still be able to operate the ***RAD7*** from DC power until the batteries recharge. Expect the recharge to take 48 hours.

Never store the RAD7 without first recharging the batteries. If you intend to store the RAD7 for a long period of time, you must recharge the batteries at least every four months, as they can be damaged by self-discharge on the shelf. Otherwise, you may have to replace the batteries before you can use your instrument again.

Battery voltage can be read from the Status display, and appears on printed output. A fully charged battery will rest at 6.40 to 6.50V. As the battery discharges, its voltage drops steadily to 6V. If the battery voltage ever goes below 6.00V, it is fully discharged and should be recharged as soon as possible. As the battery charges, its voltage rises steadily until it goes above 7V. Consider the battery fully charged if it charges at or above 7V.

7.1.7 Real-time Clock and Non-volatile Memory

The RAD7's Real-Time-Clock (RTC) and Non-Volatile Memory unit (NVRAM) allows the RAD7 operator to switch power off without losing data or disrupting the clock time and date. These functions are powered by a lithium cell with an expected lifetime of ten years.

7.1.8 Printer and Adapter

The printer is manufactured by Chamjin I&C. It comes with its own manual, and you should familiarize yourself with its operation. Specifically, you should be aware that it operates through an infrared optical link and should be positioned on the top of the RAD7 to match the data link on the detector. It runs on its own batteries.

7.2 Operating ranges

Parameter	Minimum Value	Maximum Value
Temperature	0°C (32°F)	40°C (104°F)
Relative Humidity, external (*Must be non-condensing)*	0%	95%
Relative Humidity, internal	0%	10%
Battery Voltage	6.00V	7.20V
Pump Current *(pump off)*	0mA	10mA
Pump Current *(pump on)*	30mA	90mA
High Voltage	2100V	2400V
HV Duty Cycle	8%	20%
Leakage Current *(room temp.)*	0	20
Leakage Current *(max. temp.)*	5	80
Signal voltage level	0.15V	0.30V

Table 7.2 RAD7 Operating Ranges

7.3 Service and Repair

7.3.1 Calibration

DURRIDGE maintains a radon calibration facility that includes a controlled, standard source of radon gas, and a controlled-temperature environmental chamber. All RAD7 alignment and calibration is done here, as well as basic testing and quality assurance. We determine calibration factors by direct comparison to "master" RAD7's, which were themselves compared with EPA and DOE instruments, and which have participated in international inter-comparisons of radon instrumentation. The calibration accuracy is independently verified by direct determination of the radon chamber level from the calibrated activity and emission of the standard radon source. In addition, we periodically intercompare with other radon chambers. We generally achieve a reproducibility of better than 2% with our standard RAD7 calibration. Overall calibration accuracy is in the range of 5%.

The EPA recommends (and we agree) that all continuous radon monitors be calibrated at least every six months in a radon calibration chamber, although most RAD7 users are satisfied with annual recalibration. DURRIDGE's standard RAD7 calibration requires four to five working days from the receipt of the instrument. As a preliminary to recalibration, we give every RAD7 a brief inspection, and test one or two critical parts. If additional service is required, this may delay the return of the instrument.

We recommend that you arrange for your calibration ahead of time, to avoid possible delays. When sending your RAD7 for calibration, please send the instrument only, without the accessories, and please pack it well, with at least an inch of packing all round.

At present, only DURRIDGE can make adjustments to your instrument's alignment and calibration factors. If you determine, on the basis of an independent intercomparison (e.g., another calibration chamber) that you would like to adjust your RAD7's calibration by a known amount, we can generally perform this service and send back your instrument within one day. Requested calibration adjustments of more than 10% are considered highly unusual and require the written permission of the instrument's owner.

7.3.2 Repair

If you discover that your RAD7 is malfunctioning, we recommend that you first call DURRIDGE and talk to a technician. A surprising number of minor "disasters" can be avoided by long-distance consultation. The next step, if consultation fails, usually is to send your instrument in for evaluation and repair. Please send any documentation of the problem that you might have (notes, printouts, etc.) and a short note describing the problem. Be sure that you put your name and telephone number on the note. Within 48 hours of our receipt of the instrument, we will call you to give a prognosis.

Bear in mind that a repaired instrument often requires complete re-calibration, so a one-week turn-around may be the best we can do. If you absolutely need an instrument during the repair time we can sometimes arrange to send you a "loaner" instrument.

7.3.3 Shipping

The RAD7 is shipped to you in a plastic bag, packed in a box with styrofoam peanuts, and finally packed inside another box that also holds all the accessories. The inner box, by itself, is too small for the return trip, when you need a calibration or repair job. You need to find a bigger box, with space for one inch packing all round the RAD7. A 14" cube box is fine. Pack and seal the box carefully.

Please do not ship any accessories, unless they are relevant to the problem.

All return shipments to DURRIDGE must be prepaid, and unless you instruct us otherwise, we'll return it to you via the same shipping method you used to get it to us - from "slow boat" to “next day air”, freight collect.

7.3.4 Upgrades

Whenever you send your RAD7 in for repair or calibration, you have the option of having the latest available software installed. Most RAD7's can be upgraded to the latest hardware configuration as well. You will be informed periodically of whatever new features are available for your RAD7. Please advise us if you want to have an upgrade made. We intend to keep our RAD7 customers happy by keeping their instruments up-to-date, state-of-the-art.

7.4 RAD7 Quality Assurance

While the annual inspection and calibration, carried out by DURRIDGE Company, is the most effective quality assurance, and the prime requirement of EPA, there are other tests and observations that may be made that will give assurance of good performance throughout the year.

7.4.1 Spectrum

At least once a month, the spectrum printed by the IR printer should be observed. The cumulative spectrum, printed at the end of a run, has the most data points and is, therefore, the most useful for this purpose. All that is required is that the printer be placed on the face plate at the end of a 1-day or 2-day run. It doesn't matter what format is chosen, the summary printed at the end of the run will conclude with a cumulative spectrum, after the bar chart.

Alternatively, the RAD7 will print a spectrum at the end of every cycle if the format is set to LONG. However, this will include only the counts during that cycle. For the spectrum to be useful it should have at least 100 counts. There should be clearly defined peaks and little or no noise across the spectrum. The peaks should be located in the middle of the windows. A clean spectrum is indicative of an instrument in perfect working order, and hence of reliable and accurate readings.

7.4.2 Spill Factor

Due to the occasional alpha particle emitted, from a polonium atom on the detector surface, at grazing incidence to the surface, there is always a small, low-energy tail to the peaks. This may be observed in the printed spectra. There is thus a spill of 214-Po counts from window C into window B. It is normally around 1% to 1.5% in a current production RAD7. The actual value is measured during the calibration process and the spill factor used to compensate for this phenomenon when measuring thoron in the presence of radon.

If the detector becomes contaminated in use, or either electronic or detector failure causes noise in the system, thus making the low-energy tail thicker, or the peaks broader, then this spill factor will increase. The value can be calculated from any reading, provided that it is known for sure that there was no thoron in the chamber. The percentage of counts in windows B and C is given in fields 10 and 11 of each record in memory (see Chapter 6.3.3). The spill factor is simply the ratio of the values in those two fields.

It is recommended that the spill factor be noted every month. Any sudden change is cause for further study of the instrument, and an examination of the spectrum.

8. TROUBLESHOOTING

8.1 Display

8.1.1 Blank Display

If the unit is switched on, the most likely cause of a blank display is discharged batteries. Please see Chapter 7.1.6.

Make sure the RAD7 is properly plugged in to an external power source and is switched on.

If the instrument has been run on the batteries and not recharged, or if it has been left untouched for a lengthy period, the batteries may be completely flat. In that case, the instrument should be left plugged in and switched on for many hours, preferably 24 hours or more. If this fails to restore the display, the RAD7 should be returned to DURRIDGE Company for service.

8.1.2 Frozen Display

If the display shows "DURRIDGE RAD7" and does not respond to key strokes, the key pad has been locked. Hold down the ENTER and two arrow keys until you hear a beep, release the three keys and immediately push MENU. You should then be rewarded by "Test" on the display. If the tone was set to OFF, then you will not hear the beep, so hold the three keys down for three to four seconds, before releasing them and pushing MENU, - try hold-down times a little longer, or shorter, if at first you do not succeed. Please refer to paragraph 2.2.6.

8.1.3 Incomplete Or Garbage Characters

Incomplete or garbage characters may indicate a faulty LCD display. Please return RAD7 to DURRIDGE Company for service.

8.2 Readings

8.2.1 No Counts

The total number of counts so far in any cycle is displayed in the bottom righthand corner of Status Window 1. If, near the end of a cycle, there are no counts, or less than 10, say, it probably means the cycle length is too short. Increase the cycle length to increase the number of counts in a cycle and to improve the precision of the individual readings (>Setup Cycle, HH.MM [ENTER]).

If, with a cycle time of one hour or more, the total count near the end of a cycle continues to be zero and it is known that there is radon in the sample, then either the sample path is blocked or there is a fault with the RAD7 and it should be returned to DURRIDGE Company. Check that air is flowing using any of the following measures:

a) Feel the air exiting the outlet when the pump is running.
b) Stop the outlet of the RAD7 and feel the buildup of pressure.
c) Clamp the sample input tubing, hear the change in pump sound and see the change in pump current (third status window).
d) Feel the suction at the sampling point.

8.2.2 Excessive Uncertainty In Reading

If the uncertainty in the reading is greater than the base concentration value or if there is a large scatter in the readings, the cycle length is too short for the radon concentration being measured.

Increase the cycle time to reduce the scatter. Four times the cycle time will produce half the scatter and half the uncertainty. For past data, use CAPTURE to graph the data and use "Smoothing" to smooth out the statistical scatter in the data.

8.2.3 Run/Cycle Number 0000

A Run/Cycle number of 0000 indicates that the RAD7's memory is full. Download the RAD7's contents to a computer using CAPTURE. Then erase the RAD7 data using >Data Erase. The memory will be emptied and the data structure reset.

8.3 Relative Humidity high

Relative humidity (displayed in the third status window) normally starts high unless the instrument has been well purged just before starting the run. Depending on how long it has been since the last measurement, it may take an hour or more of measurement to bring the relative humidity down to below 10%.

If it takes too long to bring down the relative humidity, check the following:

a) The desiccant is used up. Replace it.
b) The desiccant insufficiently regenerated. Follow the instructions in Chapter 7.1.1.
c) There is a leak in the drying unit. Clean the O-ring and seating before replacing the desiccant. Be sure to draw the air sample from the end furthest from the screw cap.
d) There is a leak in the connection to RAD7.
e) There is a blockage in the air path. Squeeze the inlet tubing and note any change in the sound of the pump. Feel for suction at the sampling point.

If none of the above succeed in lowering the relative humidity, there may be a problem with the humidity sensor. Measure the relative humidity of the air leaving the RAD7. If no humidity sensor is available, another RAD7, if one is available, would do. The two RAD7s can be connected in series. Set the downstream RAD7 pump to OFF (Setup, Pump, Off [ENTER]). If the downstream RAD7 reads a lower relative humidity than the upstream one, then the upstream humidity sensor is wrong and should be replaced. Return the RAD7 to DURRIDGE Company for service.

If none of these solutions are applicable, measurements made at high humidity can be corrected automatically using CAPTURE. See Chapter 3.12.2.

8.4 Water Catastrophe

If water ever enters the RAD7, or if the RAD7 ever goes swimming in the water, it will probably cease to operate and immediate steps should be taken to minimize the impact on the instrument. Keep the RAD7 upright. This will prevent water from touching the detector, which is close to the face plate at the top of the dome. Put a piece of tubing on the RAD7 outlet with the other end in a sink. Use the RAD7 pump if it still works or, otherwise, an external pump into the inlet, to blow air through the instrument. When water ceases to be blown out of the outlet, put desiccant upstream of the RAD7 to dry out the air path. When the air path is fully dry (after dry air has been blown through it for approximately one hour), remove the face plate from the case, empty the water out of the case and blow dry the case and the RAD7 electronics.

Once there is no visible water in or on the instrument, it can be put in an oven at 50℃ for a few hours to dry out completely. Additionally, desiccated air can be passed through the air path until the air leaving the RAD7 drops below 10% RH. After this treatment further corrosion will be prevented, and the RAD7 will boot once more and you can use the internal RH sensor to measure how dry the air path is. At this point the instrument should be returned to DURRIDGE for service.

8.5 Battery Voltage Low

Keep the RAD7 plugged into external power and switched on until the battery voltage (Status Window 3) recovers to about 7.1V. The RAD7 may safely be left charging all night.

8.6 Pathological Values and Error Messages

A Bad Offset Voltage error message, a 100% duty cycle, or leakage (L) above 15 (Status Window 4) all indicate faults in the RAD7, which should be returned to DURRIDGE Company without delay.

Appendix: RAD7 Specifications

Specifications for the RAD7 exceed those of all radon gas monitors made in North America, as well as those in its price range world-wide. This is a partial list of specifications that make theRAD7 so highly regarded in the field.

Part 1 Functionality

Modes of Operation	SNIFF Rapid response and rapid recovery radon measurement THORON Radon and thoron measured simultaneously and independently NORMAL High sensitivity AUTO Automatic switch from SNIFF to NORMAL after three hours run GRAB Analysis of grab samples WAT Automatic analysis of water samples with RAD H_2O accessory
Measurements	Radon in air with Sniff protocol for quick, spot reading Thoron protocol for searching for radon entry points Radon in air 1-day, 2-day or weeks protocol for long term measurement Radon in water batch samples with RAD H_2O and Big Bottle RAD H_2O Continuous radon in water with RAD AQUA and Radon-in-Water Probe Radon in soil gas with Soil Gas Probe and Active DRYSTIK Radon emission from soil and hard surfaces with surface emission chamber Bulk radon emission from bulk materials and objects
Data Storage	1,000 records, each with 23 fields of data Log of printer output also stored
Sample Pumping	Built-in pump draws sample from chosen sampling point Flow rate typically 800mL/min
Print Output	Short, medium or long format data printed after each cycle Run summary printed at end of run, including averages and spectrum
PC Connectivity	RS232 serial port, full remote control implemented in CAPTURE Software
Audio Output	GEIGER Tone beeps for radon and thoron counts CHIME Chime only at the end of each cycle, otherwise silent OFF No sound
Tamper Resistance	TEST LOCK command locks keypad to secure against tampering

Part 2 Technical Specifications

Principle of Operation	Electrostatic collection of alpha-emitters with spectral analysis Passivated Ion-implanted Planar Silicon detector SNIFF mode counts polonium-218 decays NORMAL mode counts both polonium 218 and polonium 214 decays
Built-In Air Pump	Nominal 1 liter/minute flow rate Inlet and outlet Luer connectors
Connectivity	RS-232 port up to 19,200 baud rate USB adaptor is included with every RAD7
Measurement Accuracy	+/-5% absolute accuracy, 0% - 100% RH

Nominal Sensitivity	SNIFF mode, 0.25 cpm/(pCi/L), 0.0067 cpm/(Bq/m^3) NORMAL mode, 0.5 cpm/(pCi/L), 0.013 cpm/(Bq/m^3)
Radon Concentration Range	0.1 - 20,000 pCi/L (4.0 - 750,000 Bq/m^3)
Intrinsic Background	0.005 pCi/L (0.2 Bq/m^3) or less, for the life of the instrument
Recovery Time	Residual activity in Sniff mode drops by factor of 1,000 in 30 minutes
Operating Ranges	Temperature: 32° - 113°F (0° - 45° C) Humidity: 0% - 100%, non-condensing
Cycle Range	User controllable number of cycles, from 1 to 99 to unlimited, per run User controllable cycle time, from 2 minutes to 24 hours
CAPTURE Software	Compatible with Microsoft Windows XP and 7, and Mac OS X Automatic RAD7 location, connection and data download Graphs radon, thoron, temperature and humidity over time Automatic humidity correction Statistical analysis tools track concentration averages and uncertainties Chart Recorder mode provides real-time RAD7 status monitoring Control RAD7 operations from computer via direct or remote connection Automatic calculation and display of radon in water for RAD AQUA Automatic combination of multiple RAD7 data

Part 3 Physical Specifications

Dimensions	11.5" x 8.5" x 11" (29.5 cm x 21.5 cm x 27.9 cm)
Weight	9.6 pounds (4.35 kg)
LCD Display Output	2 line x 16 character, alpha-numeric display
Case Material	High density polyethylene
Infrared Printer	Chamjin NewHandy 700 Wireless Infrared Printer included
Power Supply	11-15V DC (12V nominal) @ 1.25A, center pin positive, or included internal EnerSys sealed lead acid rechargeable battery pack (6V nominal, 30Wh, 5Ah)
Battery Longevity	24 hours in SNIFF mode; 72 hours in Monitor mode

ATTACHMENT E

BNC MODEL 940 SAM EAGLE+™ INSTRUCTION MANUAL

Instruction Manual

Model 940

Model 940 SAM Eagle+™

Berkeley Nucleonics Corporation 2955 Kerner Blvd., San Rafael, CA 94901
Phone: 415-453-9955, Fax: 415-453-9956, Email: info@berkeleynucleonics.com, Web: www.berkeleynucleonics.com

Firmware Release 03.07.01
Manual Version 6.0

U. S. Patent No. 5608222

Printed in U.S.A.

WARRANTY

Berkeley Nucleonics Corporation warrants all instruments, including component parts, to be free from defects in material and workmanship, under normal use and service for a period of one year. If repairs are required during the warranty period, contact the factory for component replacement or shipping instructions. Include the serial number of the instrument. This warranty is void if the unit is repaired or altered by others than those authorized by Berkeley Nucleonics Corporation.

IMPORTANT!! PLEASE READ CAREFULLY

NOTIFICATION OF COPYRIGHT

Table of Contents

1 Introduction

The SAM 940™ is a portable, radio-isotope identification (RIID) system that detects and identifies multiple nuclides, providing quantified results using real time and MCA analysis.

The instrument can be operated either in a very simple mode requiring no previous experience (see the Quick Start section starting on page 2) or in other operating modes that take advantage of the comprehensive set of advanced features.

The SAM 940 offers two log-on modes: **User** and **Administrator**. The **User** functions allow first line responders to perform all the tasks needed in the line of duty. The **Administrator** functions allow an experienced operator to set up the device for specific applications, and to perform additional maintenance functions. This manual will cover aspects of both, but places an emphasis on **User** functions. These are discussed more in Sections 3 and 4 starting on page 13.

After logging on, the device powers up in an initial search mode. Several different views of this mode are available, but all are based on data collected in real time. In addition to the search modes, setup, alarm review, and calibration functions can be accessed through the menu system. These are discussed in Section 3.1 starting on page 13.

The instrument has a simple user interface (described in Section 1.4 on page 3) and a wide range of setup functions and utilities (described in Section 5 on page 23).

The SAM 940 can be connected to a remote computer using Ethernet or RS232, and accessed with Quantum™ software. Quantum™ software allows:

- Up to 8 MCAs to be controlled at one time, with full spectrum data in real time.
- SAM 940 analysis in 256 QCC or linear, 512 QCC or linear and 1024 linear modes.

Note that if you are using the SAM 940 without a PC, operation is limited to 256 and 512 QCC, including the saving of spectra. However, while under control of Quantum software, all ADC modes (including 1024 linear) are available.

See Section 7 starting on page 37 for more information about available software, and Sections 2.4 and 2.5 starting on page 9 for instructions on connecting the SAM 940 to your computer.

1.1 About Your SAM 940

The basic SAM 940 unit consists of:

- The spectrometer electronics
- The gamma ray detector (normally attached underneath the instrument)
- A battery pack (installed in the rear compartment of the instrument)
- An AC power adaptor

Optional devices include:

- A neutron detector (external to or incorporated into the gamma detector)
- Quantum software
- A car power adapter
- A set of headphones and headphone adapter
- Global Positioning System

1.2 How to Use This Manual

This manual uses the following typographic conventions:

Identify, User	Soft key names are shown in bold mixed case.
Calibrate Area Monitor	Menu choices and on-screen prompts are shown in italics.
ENTER, MENU, UP	Keypad key names are shown in small capital letters.
`E:\spectra`	File or path names will be shown in typewriter font. Your PC drive letter may be different; we will use `E:` by default.

1.3 Quick Start

Getting Started

Turn on the SAM 940 by holding down the power key ⏻ (which is also the BACK key) until the BNC status screen appears. Press ENTER to move to the login screen, and then press ENTER (↵) again to advance to the user-mode search screen (generally Dial). At the bottom of the screen there will be a message indicating that auto calibration is in progress. This may take 1-3 minutes. The instrument is then ready for use.

Basic Operation

At the bottom of the screen, 3 soft keys will be seen (**Identify**, **Background**, and **Finder**). These are accessed by the LEFT (⬅) or RIGHT (➡) arrow keys and then pressing ENTER. The far right soft key allows the user to select between the available search modes. The Dial and Finder screens are the simple modes of operation where the Dial gives count rate information in the form of a speedometer. When radioactive material gives an indication in the green region, this signals proper source intensity for identification with gamma and neutron count rate (with optional neutron counter). The other colored regions indicate that the source is too far (grey) or too close (red). The Finder mode allows location of the source by displaying intensity vertically and time horizontally. The mid scale "ID"shows the proper intensity for identification. In additio n an audio signal can aid in finding the source. The other two search modes (Bars and Spectrum) are more advanced and must be enabled in the administrator menu. These two screens allow the user to view isotopes in the form of vertical "Bars"or a "Spectrum"where the isotope is identified or its presence seen in real time. These modes also show isotope category and dose rate in real time.

Identification may be performed in any one of the four modes. Simply highlight the **Identify** soft key and press ENTER. A report appears after the acquisition period. Isotopes identified are shown with a statistical confidence number ranging from 0 to 100%. This is based on source strength, length of acquisition, number of energy lines and statistical factors. The default for taking a background or acquiring a spectrum is one minute. The length of acquisition can be increased or decreased by pressing ENTER when the soft key is on +/- 30 seconds. If ENTER is held down, the length of time can be changed rapidly. Pressing the BACK key allows the user to return to the search modes. Holding down the BACK / power key for the count down of 3 seconds turns the instrument off.

Menu

Coarse calibration, review of stored spectra, thresholds, and many other features can be accessed from the user or administrator (password protected) menu. The menu can be accessed from any one of the search modes.

1.4 Description of Keypad and Soft Keys

Figure 1 shows a rendering of the SAM 940 keypad. The keypad has been designed so that it may be operated with the thumb of the same hand holding the instrument, and is accessible to people wearing protective gear as well as to both left and right-handed users.

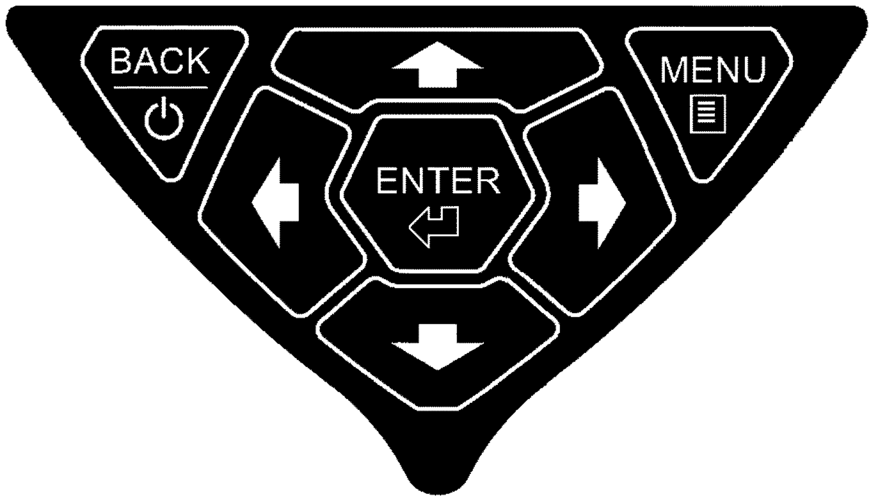


Figure 1 - SAM 940 Keypad

The following is a brief description of the seven keys and how they are used.

BACK/⏻	Returns to previous screen, exiting from menu or report. This key is also used to turn system power on and off.
MENU	Enters the menu system from any search screen.
ENTER	Used to select currently highlighted option, such as a soft key or a menu item. Also used to continue to the next step of multi-step processes.
⬅ and ➡	These keys will be referred to throughout the text as LEFT and RIGHT. They are used to select among the soft key options or menu tabs; to move backward and forward in a string entry process; to select among items in a menu choice process; and for various other applications that will be described later in the document.
⬆ and ⬇	These keys will be referred to as UP and DOWN. They are used to scroll among menu items; to scroll through reports; to change the current letter when entering a string such as a password; and for various other applications that will be described later in the document.

Many of the common operations of the SAM 940 are performed using “Soft Keys.” These are represented by a set of words in a gray bar shown at the bottom of the screen. In Figure 2, the normal soft keys seen in the “Dial”search screen are shown. The **Identify** soft key is currently selected. By pressing the LEFT and RIGHT keys, you can move the highlighting among the other soft keys, **Background** and **Finder**. Pressing the ENTER key will perform the action specified by the currently highlighted soft key, for example, entering the identification mode to collect, report, and store an analysis of a possible radioactive substance.

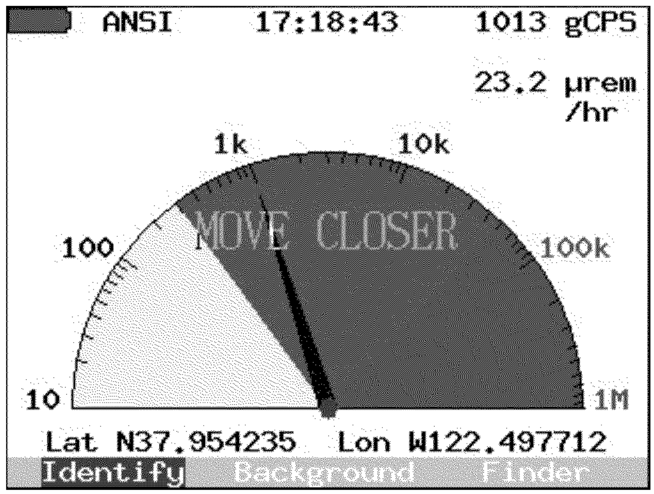


Figure 2 - Example of Soft Keys

1.5 SAM 940 Display Conventions

In order to make the SAM 940 more friendly and easy-to-use, BNC has defined several color and layout conventions for the user interface.

- Gamma and neutron radiation are distinguished by color in numbers, dials, and graphs. Gamma elements are black, and neutron elements are blue, as shown here:

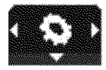
  756 gCPS
  0.02 nCPS

- Four different nuclide “classes” are defined by their colors, which appear as labels and as filled in areas in spectra. These are: blue for industrial (IND), magenta for special nuclear materials (SNM), cyan for medical (MED), and green for naturally occurring radioactive materials (NORM or NRM). In addition, when there is insufficient data to be sure something is present, it will be marked in yellow, for uncertain (UNC); and when there is something definitely present but not matched to any currently enabled nuclide, it will be labeled in red, for unknown (UNK).

  IND SNM MED
  NRM UNC UNK

- In other contexts, red is used to signal bad conditions (dead battery, calibration failure, dangerous dose rate); yellow and orange indicate concern (battery nearing end of life, calibration incomplete); and green indicating everything is normal (battery good, calibration done, OK to ID).
- Soft keys are always displayed at the very bottom of the screen, in shades of black and white.
- In most cases, where possible, small arrows are shown on the currently selected item to indicate possible choices. For example, on a selected menu tab, you can go LEFT

or RIGHT or DOWN into the menu. For some menu items, you may be able to use LEFT and RIGHT to change the value. Two examples are shown here.



- Different colors are used to group the items in each of the main menus. All sub-menus (the menus that come up within an operation selected from the menu system) are displayed in shades of gray and white. This helps you remember that if you exit this menu with the BACK key, it will only take you back to the higher level menu.

1.6 Self Test and Status Screen

When the SAM 940 is first powered on, you will see a screen that shows the results of an initial power-on self-test, or "POST." A properly functioning unit will have a display similar to t hat shown in Figure 3. The internal case temperature may vary, and of course your estimated battery life will change as batteries are charged and discharged. Press ENTER to continue to the login screen.

Figure 3 - Successful POST Screen

1.7 Choosing User or Administrator Operation

Immediately after the self-test screen, a login screen appears, as shown in Figure 4. On this screen, you have the option of logging in as the **User** or **Administrator**. The **User** functions allow first line responders to perform all the tasks needed in the line of duty. The **Administrator** functions allow a Health Physicist or other expert to set up the device for specific applications, and to perform additional maintenance functions.[1] The **User** mode can generally be accessed without a password, while the **Administrator** mode requires a password to be entered.

Figure 4 - Login Screen with User Selected

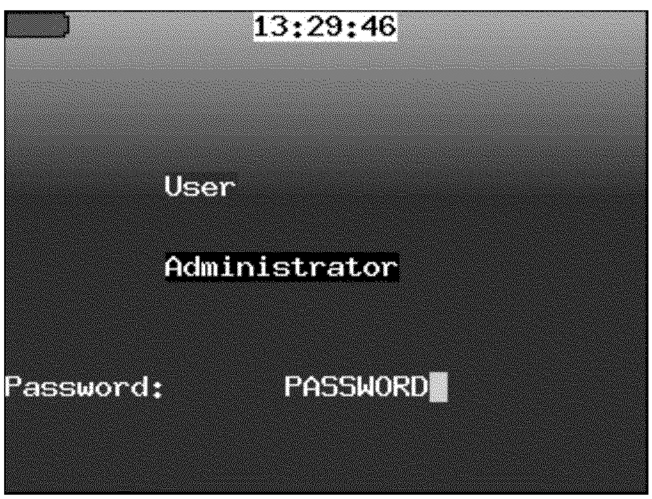


Figure 5 - Login Screen for Administrator, with Password

When entering a password, as shown for the **Administrator** in Figure 5, use the Up and Down arrows to change the letter, and the Left and Right arrows to move within the word. Holding down the Up or Down arrows will rapidly scan through the alphabet. The word *is* displayed on the screen, because otherwise it would be impossible to determine what letter is being entered! To ensure secrecy, enter the password while no one else can see the screen.

[1] These modes are designed to comply with ANSI N42.34 *Routine* and *Restricted* modes and IAEA Pub 1240 *Easy* and *Expert* modes.

2 Connections

The SAM 940 has two external connectors for power, communications, and other functions. Both are located on the part of the instrument facing away from the user, as show in Figure 6. In the lower right-hand corner is a watertight connector which provides several functions: AC power, RS232 connection, GPS connection, and headphone connection. There is a flexible black (or gray) rubber port cover at the top (shown as partly transparent here) and behind it are a CompactFlash slot on the left and an Ethernet connector on the right.

Figure 6 - Lower Front Face of SAM 940

2.1 Connecting AC Power or Car Adapter

A universal (110-240V, 50/60Hz) AC power supply is available for your SAM 940 unit. Depending on your SAM 940 model, there may be two different power supplies available. One is used only for units with an internal battery charger, and connects directly to the watertight connector. The other model requires an adapter cable, which plugs into the watertight connector. Then the AC power supply plugs into a mating plug on the adapter cable.

The car adapter plugs into a 12V accessory outlet or "cigarette lighter"outlet in your vehicle. It then connects to the same adapter cable described above, which in turn plugs into the watertight connector on the SAM 940.

2.2 CompactFlash Card

Your SAM 940 unit comes with a CompactFlash card that serves the following purposes:

- Storage for an estimated 10,000 spectra in ANSI standard (N42.42) format.
- Storage of specific system configuration information.
- Easily upgradeable system firmware.

Do not remove the CompactFlash card while the system is turned on. The system will not continue to operate without the card in place. It is best to turn the unit off, remove the card, perform whatever activities are needed, and reinsert the card before turning the unit back on. Also, it is important to note that this card is ***specific to your unit and detector***. In fact, the serial number of the electronics and detector is printed right on your particular compact flash card. Because each unit is factory calibrated for optimal performance, and this calibration is stored on the CompactFlash card, the cards should never be exchanged between different units. Also, the contents of the card should not be erased, except through the menus provided in the SAM 940 itself (see Section 5.2.1 beginning on page 26).

You may wish to read the saved spectral information on the card using your PC. If your PC includes a media reader bay, you should be able to insert the card and read it as simply as you would access a CD-ROM or floppy. If your PC does not have a media reader built in, a simple USB interface is available as an accessory. In either case, the device will be assigned a drive letter (often `D:`, `E:` or `F:` – we will assume `E:` throughout this document). The spectra may then be read from the directory `E:\spectra`.

For more information on reading spectral files and the software you can use for these purposes, see Section 7 starting on page 37.

2.3 Batteries

Your SAM 940 comes equipped with a rechargeable battery pack (8 rechargeable AA batteries). This battery pack may be in a holder than can be removed, or in a compartment with a removable cover. They can be quickly replaced with another set for continued operation. The battery compartment is highlighted in Figure 7, and may be secured by thumb-screws or threaded screws. Models with thumbscrews on the bottom require removal of the detector as described in Section 2.8 in order to gain access to the batteries.

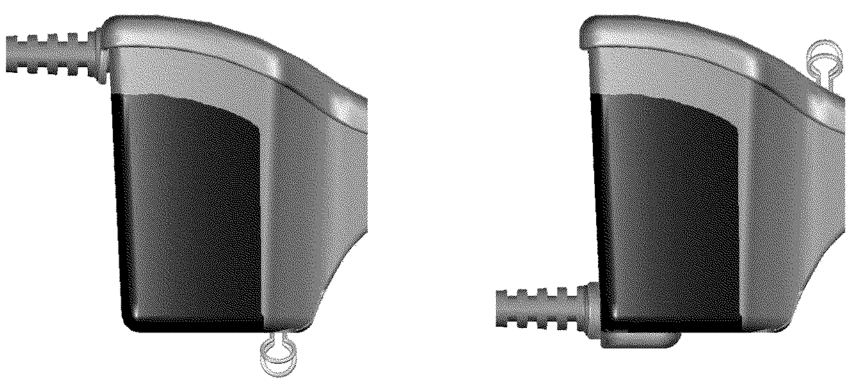


Figure 7 - SAM 940 Battery Compartment (Highlighted)

Depending on usage, the SAM 940 will generally run 6 to 8 hours on a single charge when the recommended batteries are used. If necessary, AA alkaline batteries can be used instead, but the run time on these is shorter, generally only 3-5 hours. There are several things you can do to improve your battery life:

- Reduce the display brightness as low as possible without affecting your ability to read the display. If operating out-of-doors, you may find that the reflected sunlight is sufficient to read the display even with the brightness at its minimum setting.
- Turn off the *Audible Count Rate* and/or *Mute* the speaker.
- Shorten the *Backlight Timeout* so that the display darkens when you are not using the system.
- Disconnect the batteries and use only AC power when connecting to a PC or doing other stationary operations in the office. The unit will automatically run from AC power if it is available.

For your safety:

- If the SAM is not being used and if the batteries are fully charged, do not leave the SAM connected to the AC power adaptor.
- If you choose to use rechargeable batteries other than the factory supplied battery pack, do not attempt to recharge the batteries while installed within the SAM.
- If you choose to use standard alkaline batteries, do not connect the AC power adaptor without first disconnecting the batteries.

2.4 Ethernet Connection for Data Output

In addition to accessing data directly on the CompactFlash card, the Ethernet connector (also shown in Figure 6 above) can be used to connect your SAM 940 unit to a building network or to your PC. By making this connection, you will be able to access data on the unit, including operating it remotely with the Quantum™ software.

If you are connecting to an Ethernet switch or hub, a standard CAT-5 Ethernet cable can be used. If you wish to connect directly to your PC, you will need a special "crossover" cable that takes the place of the switch or hub.

1. Connect the SAM 940 to the local Ethernet using a CAT-5 or better Ethernet cable.
   A. If connecting to a hub or switch, use a standard or "straight through" Ethernet cable.
   B. If connecting directly to a PC, use a "crossover" Ethernet cable.
2. Connect the other end of the cable to the host computer, hub, or switch.
3. Power on the SAM 940 and log in as the **Administrator**.
4. Press the MENU button key to go to the menu, and move right to select the *Admin* menu.
5. If this is your first time using Ethernet communications from this unit, or if you have moved the unit to a new network, you may need to enter information into the *Network Setup*. This procedure is detailed in Section 5.3.12 starting on page 32. Otherwise, you will only need the IP address setting of the SAM 940 for use in step 8 below.
6. Move down to select the first item, *Remote Mode*. Press the ENTER key to select remote operation.
7. Click on the Quantum™ hardware search icon  to open the **MCA Devices Auto Configuration** program.
8. Select **Ethernet, ANS Ethernet,** and **Quantum Ethernet**. Enter the IP address given to you by your system administrator or entered in step 5.
9. Click the **Update** button. If the connection is successful, the SAM version number and serial number will display on the **MCA Devices Auto Configuration** screen.

10. In addition to the reference information found in the Quantum software manual, detailed startup and calibration procedures can be found in the supplemental application notes in the "DOC" folder on the Quantum CD. Both PDF versions (for quick, on-screen reading) and Word documents (for better printing) are included. Start with the application note "QtmInitialCalibration," which includes software installation notes and hardware connection information. If you have an earlier version of Quantum without this document, contact BNC to have a PDF version e-mailed to you.

2.5 RS232 Connection for Data Output

As an alternative to the Ethernet connector, the watertight connector (also shown in Figure 6 above) can be used to connect your SAM 940 unit directly to the RS232 port of your PC. By making this connection, you will be able to access data on the unit, including operating it remotely with the Quantum™ software.

A special RS232 adaptor is required and you will need a "crossover" or Null Modem serial cable.

1. Connect the 8-pin circular connector of the RS232 adaptor to the watertight connector.
2. Connect the 9-pin sub D connector of the RS232 adaptor to a crossover / Null Modem cable.
3. Connect the other end of the crossover / Null Modem cable to the serial port of the host PC.
4. Power on the SAM 940 and log in as the **Administrator**.
5. Press the MENU button key to go to the menu, and move right to select the *Admin* menu.
6. Make note of the Serial Mode/Speed setting (either Comm 115K or Comm 19.2K).
7. Use the UP or DOWN buttons to select the first item, *Remote Mode*. Press the ENTER key to select remote operation.
8. Click on the Quantum™ hardware search icon  to open the **MCA Devices Auto Configuration** program.
9. Under "General Categories of Devices" enter a check mark in the Serial Port box.
10. Under "Specific Device Types" enter a check mark in the PGT/ANS COM box.
11. Under "Include in Search" enter a check mark in the Quantum COM or Prospector box that corresponds with the available serial port to which you attached your RS232 cable. Under Include in Search enter a check mark in the Quantum COM or Prospector box that corresponds with the available serial port to which you attached your RS232 cable. *Typically COM 1 or COM 2*
12. Set the "Baud Rate" value to match the Serial Mode/Speed setting from your SAM 940 (either 115200 or 19200 as noted in Step 6).
13. Click the **Update** button. If the connection is successful, the SAM version number and serial number will display on the **MCA Devices Auto Configuration** screen.
14. In addition to the reference information found in the Quantum software manual, detailed startup and calibration procedures can be found in the supplemental application notes in the "DOC" folder on the Quantum CD. Both PDF versions (for quick, on-screen reading) and Word documents (for better printing) are included. Start with the application note "QtmInitialCalibration," which includes software installation notes and hardware connection information. If you have an earlier version of Quantum without this document, contact BNC to have a PDF version e-mailed to you.

2.6 GPS Connection

If your SAM 940 unit is equipped with the GPS Option, the watertight connector (also shown in Figure 6 above) can be used to connect your SAM 940 directly to the supplied GPS receiver.

A special I/O adaptor is required to connect the GPS data cable to the watertight connector.

1. Connect the 8-pin circular connector of the I/O adaptor to the watertight connector.
2. Connect the 9-pin sub D connector of the I/O adaptor to the GPS data cable.
3. Connect the other end of the GPS data cable to the GPS and turn on the GPS.

4. Power on the SAM 940 and log in as the **Administrator**.
5. Press the MENU button key to go to the menus, and move right to select the *Admin* menu.
6. Use the UP or DOWN buttons to move to the *Serial Mode/Speed* setting.
7. Use the LEFT or RIGHT buttons to select GPS NMEA. (If you do not have a GPS license key, the GPS NMEA selection is not available.)
8. Use the UP or DOWN buttons to move to the *Logging Interval* setting.
9. Use the LEFT or RIGHT buttons to select OFF, 1 sec, 2 sec, or 5 sec.
10. Latitude and longitude will be displayed on the Search Mode Screen during normal operation, and they will be included in Analysis Reports.

2.7 Headphone Connection

Additionally the watertight connector (also shown in Figure 6 above) can be used to connect your SAM 940 unit to headphones. By making this connection, you will be able to hear count activity, alarms, messages, and warnings in sensitive environments.

A special I/O adaptor is required to connect headphones to the watertight connector.

2.8 Detector Connection

The detector is mechanically attached to the SAM 940 with a single quarter-turn thumbscrew located in the handle, as shown in Figure 8. Although this operation configuration makes one-handed use easy, the detector may be detached from the electronics unit for certain special applications or to access the battery compartment. To do this, flip up the metal ring in the middle of the handle, as shown in the Figure. Rotate it ¼ turn counter-clockwise to detach. When re-attaching the detector, first be sure that the two handles are correctly seated by squeezing them together with your hand. Then, push down slightly on the connecting screw, rotate it ¼ turn clockwise, and flip the ring back down into the recess on the SAM 940 handle.

To move the detector further from the electronics, an extension cable may be attached. A special water-tight LEMO connector is used on your detector, which is released by gently pulling backward on the textured grip. ***Do not* try to turn this connector to remove it –** it pulls straight out, and forcing the connector to turn may damage the cable or the detector.

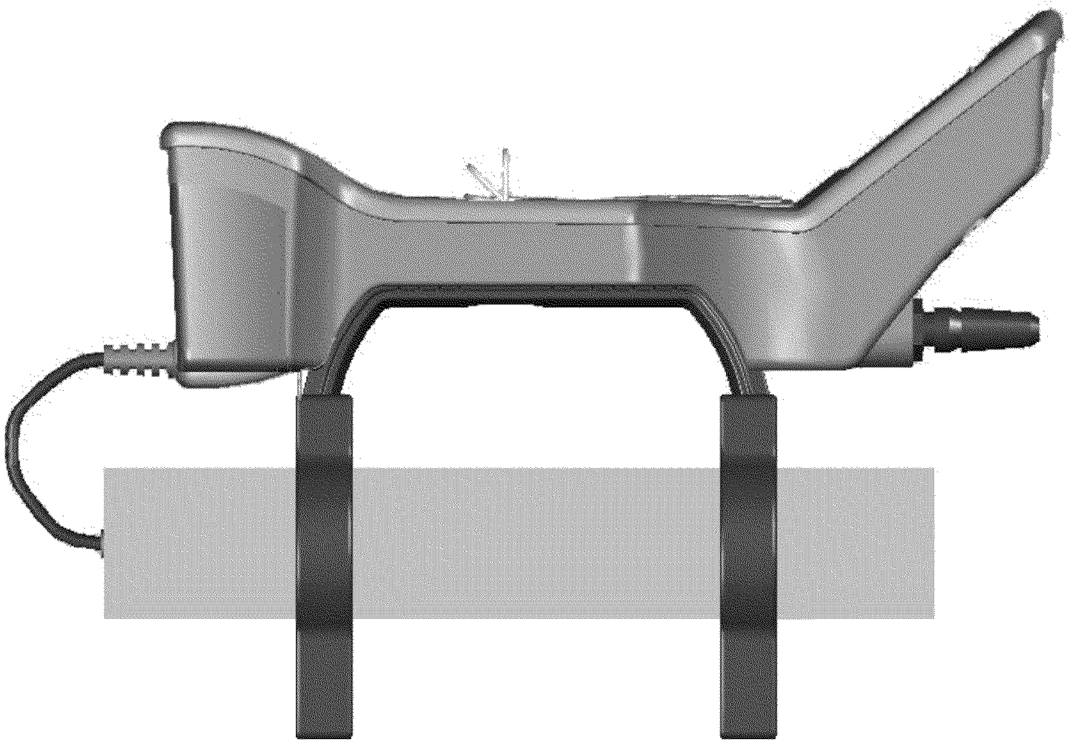


Figure 8 - Side View of SAM 940 with Detector

For customers with existing SAM 935 detectors, a special adapter cable is required because these detectors have a higher supply voltage requirement.

2.9 Neutron Detector Connection

Special instructions for the He3 Neutron Detector Option to be added here.

3 General Operation

The following sections describe the standard operating procedures for the system including the different operating modes.

3.1 Turning the Power On and Off

Turn on the SAM 940 by holding down the BACK / ⏻ key until the BNC status screen appears. (See Section 1.5 for more information about this screen.) After navigating past the self-test and the login screens, the SAM will display the Search Mode Screen (see Figure 9 on the following page.)

Sodium iodide detectors normally stabilize about 10 minutes after the power is turned on, assuming a stable temperature environment. However, the SAM 940 has a built-in stabilization feature that will generally complete a recalibration within three minutes. During this time, it will display an informational message at the bottom of the screen indicating that AutoCalibration is in progress. Although, in an emergency, data can still be collected while the unit is stabilizing, the built-in analytical software may not make correct identifications during this time. After "AutoCal is Complete" appears at the bottom of the screen, the message goes away, and the SAM is ready.

To start taking readings, see Section 3.2, "Search Modes" below and Section 3.4, "Identifying Sources of Radiation" on page 18.

Whenever the SAM 940 is turned off, all information is saved on the CompactFlash card, allowing you to restart the instrument without losing calibrations or other information. The real-time clock has a separate internal lithium battery that keeps it running even when there is no other power source.

To turn the SAM 940 off, press and hold the BACK / ⏻ key. After one second, a message will appear and count down three seconds before the system turns off. In the rare event of a system lock-up, it may be necessary to hold the key down for a longer period of time (10 seconds) in order to engage the fail-safe power-down mechanism.

3.2 Search Modes

The "search" modes are the modes normally used to detect the presence of radioactivity and determine its location. They respond quickly and make it easy to tell if something has changed, but give less detailed analytical results. In these modes, the instrument continuously takes readings, searches for isotopes, and analyzes them for dose rate and other measurements.

There are four search modes available, called *Dial*, *Finder*, *Bars*, and *Spectrum*. Only *Dial* and *Finder* are enabled by default when logged in as **User**. However, your **Administrator** may change which screens are enabled, so that it is easier to quickly access the most important information for your particular response plan. To learn more about enabling and disabling features, see Section 5.3.12 beginning on page 32.

There are a number of common elements that appear on all of the search mode screens. These are shown on the *Dial* screen in Figure 9.

In the upper left corner is a battery icon, which shows in green when the batteries have at least ten minutes of useful life remaining. It shows in yellow when the batteries have between 5 and 10 minutes left, and it shows in red when the batteries have less than 5 minutes left. When the time is short, the battery icon will indicate a remaining time in hours and minutes. Please note that these times assume the system is running on the factory-provided batteries, and are still somewhat approximate as the battery life can change with use and from one charge cycle to another.

Just to the right of the battery is a message indicating the currently selected Trigger List. The Trigger List is the list of all of the nuclides that are currently enabled for detection and analysis. Knowing the kind of nuclides you normally search for will help reduce false identifications. To learn more about this feature, see Section 5.3.12 beginning on page 28.

In the top center, the screen displays the clock time. It is important to have this time set correctly, including your time zone, so that the stored spectra will have the correct time recorded.

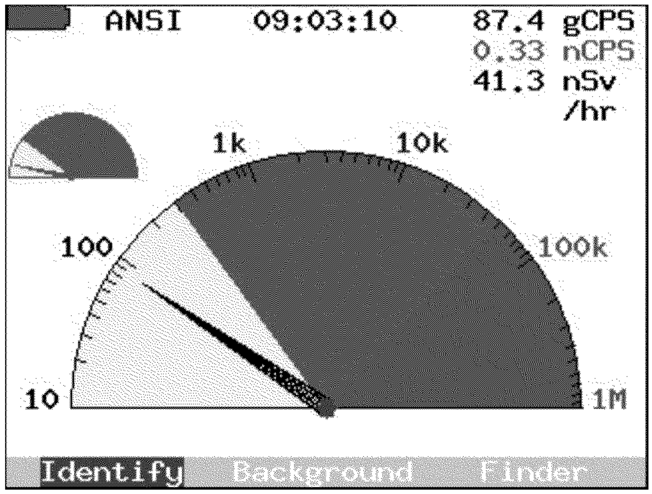


Figure 9 - *Dial* Search Mode Screen

The three numbers in the top right corner indicate the count rate for gamma rays (black) and neutrons (blue) and the current dose rate. These help associate specific numbers with the visual elements of the dial. If your system does not have a neutron detector, the blue neutron count rate and neutron dial will not appear – this version of the display is shown in Figure 10.

Finally, at the bottom of the screen you will see three soft keys: **Identify**, **Background**, and one additional choice that allow you to move to the next search display mode. (On systems where only one mode is enabled, only the first two keys will be shown.)

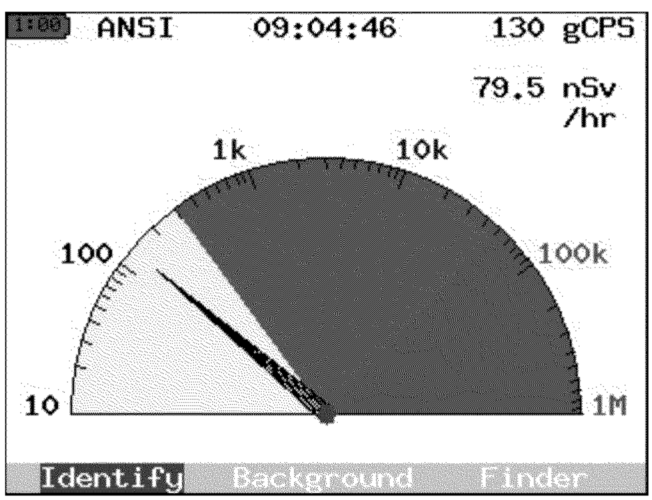


Figure 10 - *Dial* Search Mode Screen without Neutrons

The main purpose of the *Dial* screen is to provide a quick visual indication, similar to that given by a handheld dose meter or Geiger counter, showing the amount of radioactivity being measured.

When the dial pointer is in the gray area, there is little radioactivity present – most of the counts are coming from either cosmic rays or naturally occurring sources such as potassium-40.

Once the pointer moves up into the green area (on either the gamma dial or, if present, on the neutron dial), there is an indication of some unusual activity. Within the green area, an **Identify** operation (described in Section 3.4 starting on page 18) should be started. Finally, if the pointer moves into the red area, the activity is too high for a correct identification. It is <u>*strongly advised that you move back from the radioactive source*</u>, if at all possible, before attempting to identify it.

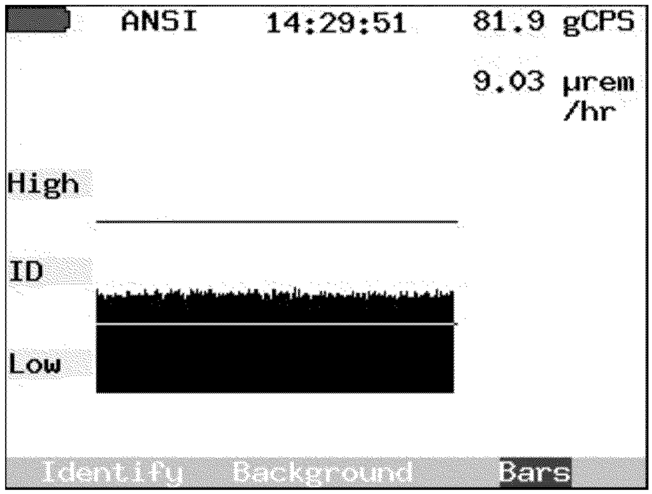


Figure 11 - *Finder* Search Mode Screen

The *Finder* screen shows a similar type of count-rate-based information. However, it is displayed as part of a bar graph that continually moves to the left at 10 steps every second. The full chart displayed on the screen represents approximately the last 20 seconds. This mode can be extremely helpful when you are walking through an area looking for a radioactive source. The system is giving you “cold/warmer/hot”feedback as you move, so that you can localize the source effectively. Once you have narrowed in on the source, you should do an **Identify** operation. The “low”area shown on the screen corresponds to the gray area on the *Dial*; the “ID”area matches the green portion; and the “high”area matches the red portion. **Identify** will be most effective when the top of the rolling chart is falling within the ID area.

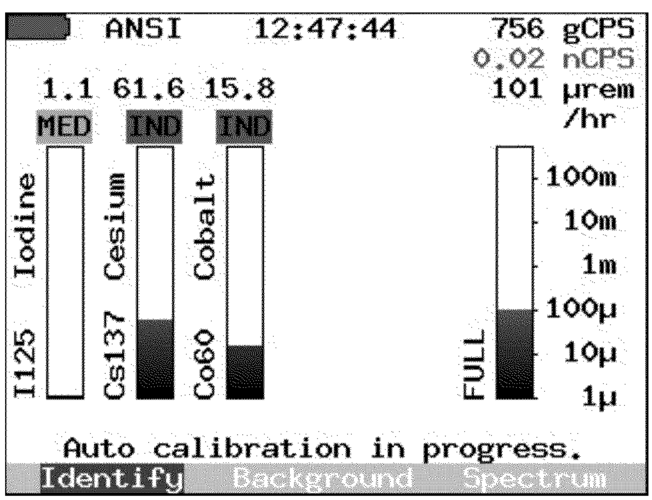


Figure 12 - *Bars* Search Mode Screen

The *Bars* screen provides a very different sort of information, organized around *what* is present rather than on *how much*. The numbers at the top right still indicate the count and dose rates, but the individual bars indicate the different radioisotopes that are thought to be present. The symbol and name of the isotope are listed to its left. Above each bar is a "class" indication. Each bar shows an estimated dose rate attributable to that particular isotope.

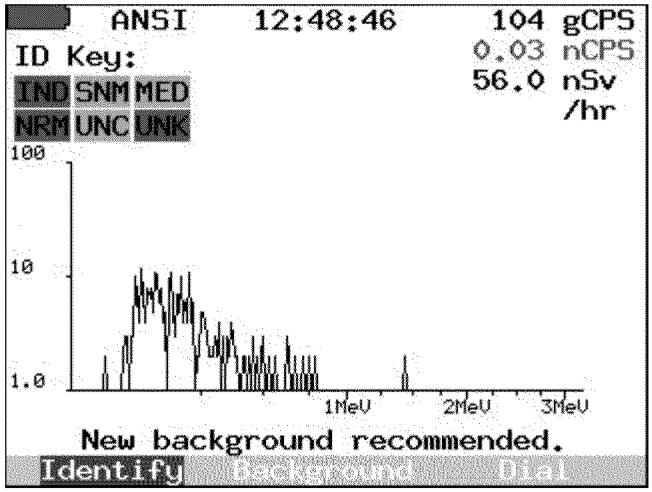


Figure 13 - *Spectrum* Search Mode Screen

The *Spectrum* screen is designed for users with a Health Physics background to see the data collection and statistics in real time. Certain changes in the spectrum shape, such as that produced by beta particle interactions, can be interpreted by the trained eye, even when it cannot be identified by the automated algorithms. This screen provides a dynamic display for this particular set of users.

3.2.1 Audible Search Setting

All of the search modes described above are visually-oriented. There may be times when watching the display screen is inconvenient - either because you need both your hands free for other activities, or because you need a more inconspicuous way to monitor for radiation. In addition, the human ear is surprisingly sensitive to changes in rate, so you may find that you can better tell whether you are seeing abnormal radioactivity by enabling the audible output.

The *Audible Count Rate* setting in the *Field Settings* menu turns on a click that increases in frequency along with the input count rate. This sound continues as long as the instrument is collecting data, so it also gives feedback when you are in menus and other screens that do not show count rate information. In the same menu, you can also mute the internal speaker if you want to use the optional headphone attachment. These menu items are shown in Section 5.2.2 starting on page 28.

Note: Enabling the *Audible Count Rate* may noticeably reduce your battery life.

3.3 Taking a Background

To ensure accurate results, it is very important to take frequent background spectra in the actual monitoring location. The background is the point of reference against which readings are measured, and corrects for ambient radioactivity or background from cosmic rays in the area of the detector. The ambient background spectrum is stored and then subtracted from all other collected spectra on a channel-by-channel basis before they are analyzed.

It is easy to take a new background on the SAM 940. Use the LEFT or RIGHT buttons to simply select the **Background** soft key and press ENTER. First, the system will remind you to ensure that any known sources of radioactivity are properly stored or shielded, as shown in Figure 14.

Whenever you are ready, you may **Continue**. If you need more time, you may **Wait** or even **Cancel** if necessary. If the countdown completes, the system will continue for you.

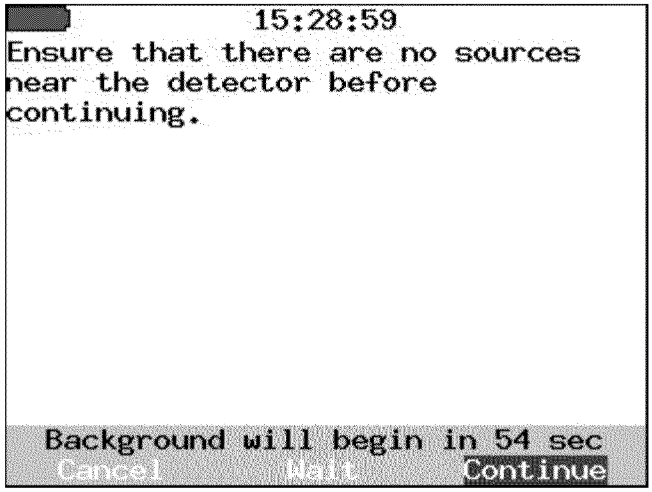


Figure 14 - Collecting Background - Instructions to Remove Sources

Once you continue, you will see a display like that shown in Figure 15. Initially, the graph will be fuzzy (lack of statistics), but it should smooth as time goes on. If you wish to collect a longer background, you can increase beyond the default time by selecting **+30 s**; holding down the ENTER key will rapidly increase the collection time. You also have the option to shorten the collection time, to **Cancel** at any time, or to **Erase** (for example, if you believe that you have forgotten to shield all sources in the vicinity). When this new countdown completes, the system will be ready for operation.

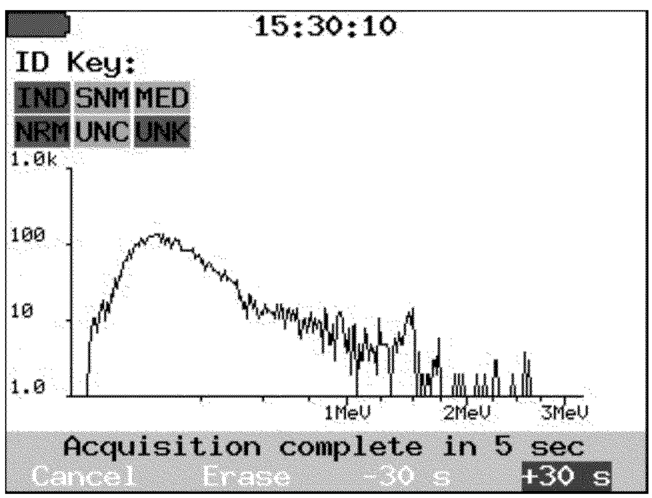


Figure 15 - Collecting Background - Typical Spectrum

Background spectra can be acquired at any point, and should be taken:

- Whenever the ambient background changes (for example, if the instrument is moved to a new location).
- Every week, as prompted by the SAM 940.

Because the counting statistics in the background spectrum directly affect the uncertainty in the analyzed spectra, the background should be counted for as long as or longer than the acquisition time.

Normal readings will have significant variations based on location and detector size. Only with experience can the user determine what "normal" CPM readings are. The most likely causes for high background readings are:

- The presence of radioactive materials near the system in the form of samples or standards.
- High concentrations of natural radioactive material such as K40 in the building materials.

Less likely causes include:

- High radon levels.

3.4 Identifying Sources of Radiation

Once the SAM 940 has helped you locate a radioactive material, it can help you determine the specific material that is present. The system has an internal library of over 40 nuclides. However, at any given time, only the subset defined by the current *Trigger List* is enabled. You can change to different trigger lists by using the *Select Trigger List* item in the *Field Settings* menu. This is described in more detail in Section 5.2.2 starting on page 28.

To collect data for identification, simply select the **Identify** soft key on the search mode screen. The system will immediately begin to collect data for identification. An example is shown in Figure 16, with the industrial nuclide Cs137 present. As soon as the system has identified the nuclide(s) present, it will color in the peaks with their appropriate class color: blue for industrial (IND), magenta for special nuclear materials (SNM), cyan for medical (MED), and green for naturally occurring radioactive materials (NORM or NRM).

Do not be concerned if some parts of the display are marked in yellow – these are an indication that the system is uncertain whether there is an actual signal or "peak"present in the spectrum. If you wish to eliminate these uncertainties, you can extend the collection time by using the **+30 s** soft key until the uncertainty has been resolved, but this is rarely necessary.

When there is a definite peak present but it does not match any nuclide on the current trigger list, it will be labeled in red, for unknown (UNK). In this event, it may be valuable to re-analyze the data with another trigger list, to see if the relevant nuclide was not enabled. If no analysis can be found, it may be time to consider sending the spectrum to a Reachback center, as described in Section 6.3 starting on page 37.

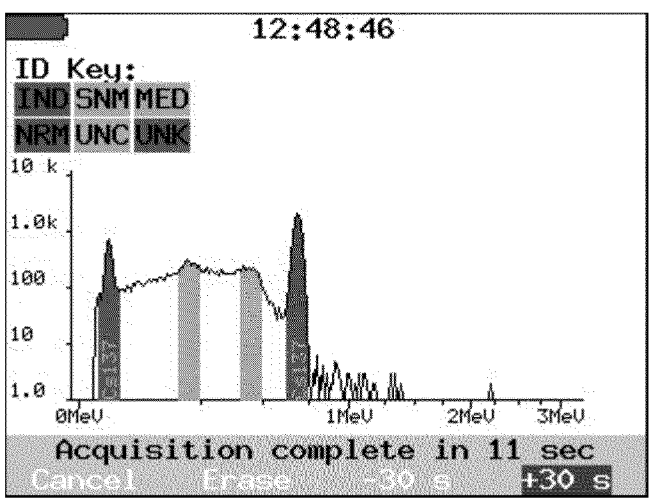


Figure 16 - Identify in Progress with Cs137

Once identification is completed, an analysis report will be presented, as described in the next section.

3.5 Analysis Report

The analysis report gives the results of a detailed analysis of the collected data. An example of this is shown in Figure 17. Different details of this report may be enabled for different applications.

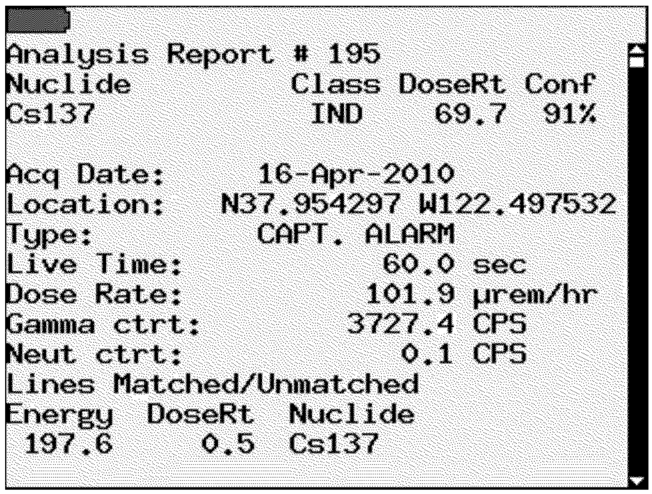


Figure 17 - Sample Analysis Report of Cs137

The initial part of the report shows the date the spectrum was acquired, the type (a manually captured alarm), the collection time, and the same dose rate and count rate information normally shown on the main screen.

Immediately after these lines is the "found nuclides"report, which gives some of the most critical information. It shows the name of any suspected nuclides, the class identification, the nuclide-specific dose rate (in the same units as above), and the confidence in this particular identification.

The final lines in the report detail the hardware settings used in the data collection process.

3.6 Storing, Reviewing, and Erasing Spectra

Spectra are automatically saved whenever an **Identify** process is completed. Spectra are also saved for each background taken and for certain other operations like fine energy calibration. The SAM 940 can store nearly 10000 spectra in its "catalog." Each stored alarm consists of a spectrum and all the information necessary to analyze it. They are stored in a standard format designed to comply with ANSI N42.42.

You can review and (when desired) erase these spectra using the *Spectral Data* menu, described in detail in Section 5.2.1 starting on page 26.

4 Manual Calibration

Occasionally, you may find it desirable to re-calibrate your instrument manually, rather than relying on the built in calibration mechanism. We recommend doing this calibration under the following circumstances:

- Perform a *Coarse Calibrate with Cs137* and a background spectrum acquisition when you first install the instrument on site. Although the instrument is factory calibrated, the on site calibration allows a check for accurate calibration.
- Perform a coarse adjustment whenever the unit has been subjected to a severe temperature change, such as the trunk of your car to the inside of a building. This is particularly important if the unit was turned off at one temperature (e.g., indoors) and turned on again at another (e.g., right after spending a long time in your car).

The collection of a new background was already detailed in Section 3.3 starting on page 16. The manual calibration procedure is detailed below.

4.1 Coarse Calibration

The recalibration procedure described in this section automatically adjusts hardware parameters (for example, high voltage and amplifier gain) to obtain an accurate system energy calibration. It requires one radioactive source, a license-exempt Cs137 source of approximately 0.5 to 5 μCi.

To begin the process, you must enter the menu system by pressing the MENU button. Press the RIGHT key and you should immediately see a *Field Settings* menu that looks similar to Figure 18. By pressing the UP or DOWN arrow keys, move the selection so that *Coarse Calibrate with Cs137* is selected. Press ENTER to begin the calibration.

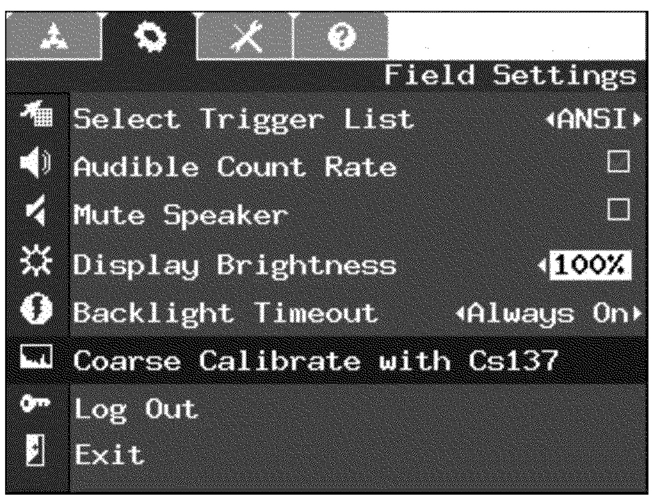


Figure 18 - *Field Settings* Menu with *Coarse Calibrate* Selected

You will now be prompted (as shown in Figure 19) to place the Cs137 source near the detector. If you do not have the source close at hand, you can ask the system to **Wait** (give you an extra minute) or **Cancel** if you made a mistake.

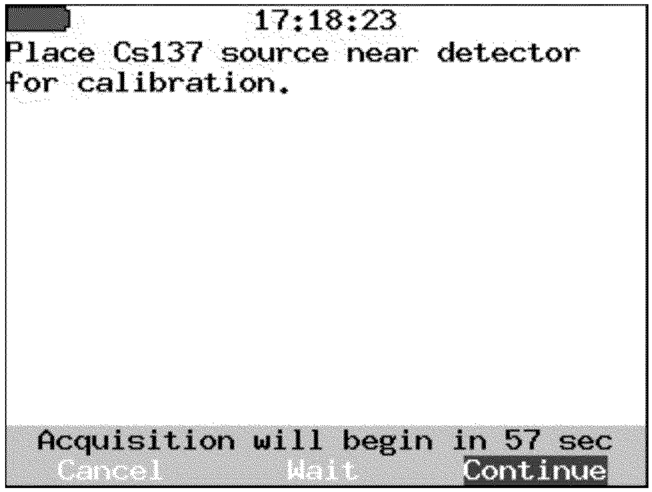


Figure 19 - *Coarse Calibrate* Source Placement Dialog

Once you **Continue** (or allow the countdown to complete) you will see a screen that looks similar to the one shown in Figure 20. This process may repeat several times as the system updates different parameters to ensure that your calibration is as close as possible to the target calibration. The target calibration is shown by the two blue/gray lines near the centers of the peaks. Do not be concerned if the parameters shown in the message area above the soft keys are different than shown in Figure 20 – they are unique to each detector type and detector.

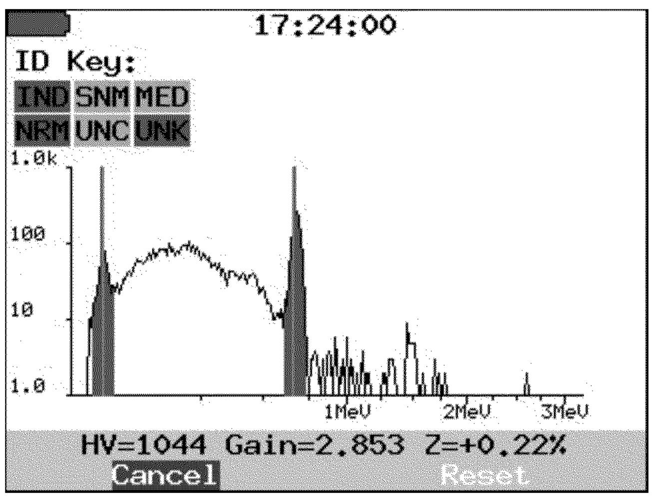


Figure 20 - *Coarse Calibrate* Collecting Data

When the process is complete, the system will beep three times (unless you have the speaker turned off) and return to the *Field Settings* menu.

If for some reason your system is having trouble seeing the peaks – for instance, if the peaks are already far to the right of where they should be – you can also select the **Reset** soft key to initialize all the parameters to defaults. Please be aware that resetting all the parameters will make the calibration take a much longer time than normal. If the calibration does not look right or is taking too long, you can always **Cancel** and go back to the previously stored calibration.

4.2 Dose Rate and Fine Energy Calibration

Your system has two additional calibrations that are performed at the factory. One corrects the dose rate for individual variations in the detector efficiency; the other ensures that the energies of measured radiation lines are correct across the entire spectrum.

If for some reason you believe these calibrations are no longer correct, or if your regulations require periodic recalibration of the instruments with NIST-traceable sources, please contact the factory for more information.

5 System Menus

The following sections describe how to use the menu system, and show the different settings that can be adjusted from each menu.

5.1 Using the Menus

Before describing each of the different menus in detail, this section shows and explains how to choose the menu, how to choose an item within the menu, and how each of several standard menu editing operations works.

First, to enter the menu system, you must press the MENU key while in one of the search mode screens.

When you first enter the menu system, you will start with the *Spectral Data* menu (details for this menu will be discussed in Section 5.2.1 on page 26. Press the RIGHT key and you should immediately see the *Field Settings* menu. Figure 21 shows the menu "tabs" that appear if logged in as **User**. The second tab from the left corresponds to *Field Settings*, and so it is shown highlighted in color, while all the other (unselected) tabs are shown in gray. The name of the menu, "Field Settings," also appears just below the tabs as shown. To change to another menu when the tab is selected, you may use the RIGHT and LEFT arrow keys. (In this case, the RIGHT arrow key will take you to the *Spectral Data* menu, while the LEFT arrow key will also wrap around and bring you to the *Help* menu.) If you are somewhere in the middle of a menu, and want to quickly return to the tabs, you can press the MENU key to do so.

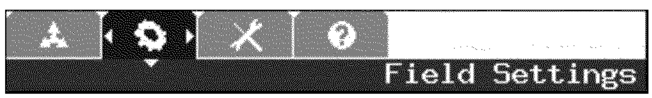


Figure 21 - Example of Menu Tabs

To select an item from the menu, press the UP or DOWN arrow keys. Pressing the Down arrow when on the tab will take you to the first item on the menu. Alternatively, as a shortcut, pressing the Up arrow when on the tab will take you to the *last* menu item.

To return from the menu system to the search mode, you can use the BACK key (unless you are running a procedure or editing a specific item) or you can select the *Exit* item at the bottom of each menu.

We will now elaborate on how to make changes for various types of menu items.

5.1.1 Run a Procedure/Display Information/Open Submenu

Perhaps the simplest type of menu item is one which either runs a procedure, displays information (such as a help file), or opens a sub-menu. These all look the same on the screen, except for the name of the menu item. The *Coarse Calibrate with Cs137* item is shown here as an example.

To perform the listed task, simply move the highlighted area (darker background) onto this menu item, and press ENTER. In the case of a procedure like calibration, the first step of the procedure will then be displayed. For a help menu item, the associated help text is displayed.

5.1.2 Check Option On or Off

Another simple procedure is to turn an option on or off. For these items, a check-box is shown, as in the example of the *Audible Count Rate*.

To change whether the option is enabled or not, highlight the menu item and press Enter to toggle the check mark. Alternatively, the Left and Right arrows also toggle the check mark.

5.1.3 Adjust Slider

A few features are set with sliding adjustments like the ones you might find on your PC monitor. The *Display Brightness* is shown as an example here.

To change the value, highlight the item and press the Left arrow key to reduce the value, or the Right arrow key to increase it. The value is shown both in percent and as a bar that goes from empty (0%) to full (100%). The small arrows shown on the screen are a reminder that Left and Right are the keys you use to make a change.

5.1.4 Select Among Options

Some items give you a choice among different static options. *Select Trigger List*, shown here, gives you several standard options to choose from.

Pressing the Left or Right arrow will change to the previous/next item in the list. The small arrows shown on the screen are a reminder that Left and Right are the keys you use to make a change. In cases where there is no particular order to the list, you can continue flipping through items until you come back around to where you started. For other items, like time intervals, there may be a minimum and maximum value. When the minimum is reached, the left arrow disappears from the screen and Left will no longer make a change; the same is true for Right when the maximum is reached.

5.1.5 Edit Numeric Value

A few options, particularly those available to the **Administrator**, are numeric values that may need to be changed. The *Dose Rate Alarm Level* setting is shown here.

There are two mechanisms for changing these values. When the menu item is first highlighted, pressing the Left key will reduce the value to a smaller value – sometimes half, sometimes another convenient interval – until it reaches a minimum setting. Pressing the Right key will increase the value up to a maximum.

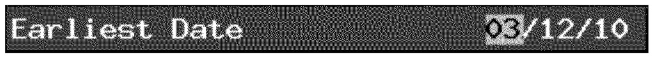
If the existing steps are not satisfactory, you may change the value one digit at a time by entering the "free edit"mode. This is done by pressing Enter while the menu item is highlighted; you will see the display change to appear like the display here:

Once in this mode, Left and Right move to a different digit, and Up and Down change the currently highlighted digit. In order to accept your changes, or in order to use Up and Down to move to the next menu item, you must press Enter. This will save the current value and put you back in the normal menu-browsing mode.

5.1.6 Edit Date for Filter

When choosing a date for *Spectrum Search Criteria* menu, the menu item works in a way similar to the Edit Numeric Value function. Initially, *Any* date is allowed.

If you wish to make a restriction, so that fewer dates match, you must edit the value. Pressing an arrow key will change the date to today's date; pressing an arrow key again will change it back to *Any*. To edit the date, you must press Enter.



While in this mode, you may change each portion of the date by using the Up and Down arrow keys. (Note that the actual format of the date may vary depending on your *Language* choice.) Pressing Up or Down a US date format (as shown above) will change the month to April or February. Pressing the Left and Right keys will change to another field. When you have the date you would like, press Enter to return to the normal mode.

Note that, if you press the Left and Right arrow keys again, the date will change back to *Any*. However, the system will remember the date you entered and if you press the arrow key again, you will get back your edited date.

5.2 User Menus

Four menus are available to the **User**: *Spectral Data, Field Settings, Config,* and *Help*. The items on these are the ones most often needed in general operation. The same menus appear for the **Administrator**, but may have additional options shown. All the common options are described in this section, and only the new ones for the **Administrator** are described in Section 5.3.

5.2.1 Spectral Data

Figure 22 shows the *Spectral Data* menu. The items on this menu allow you to navigate through the stored spectra, search for particular spectra, review, and delete those spectra. This menu is the same for both **User** and **Administrator**.

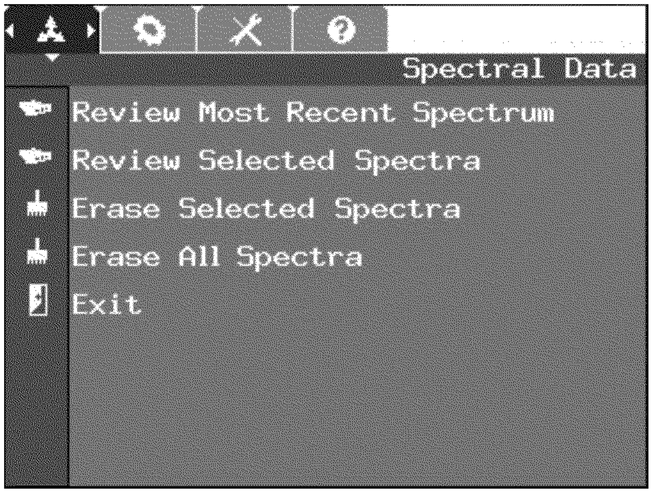


Figure 22 - *Spectral Data* Menu

By highlighting and selecting the *Review Most Recent Spectrum* operation, you are able to do just exactly that. The screen will display the most recently captured spectrum whether it is the result of a "captured alarm", a "background", or a "calibration"operation. By pressing the E NTER key again, you are able to view the most recent Analysis Report associated with that spectrum.

When either the *Review Selected Spectra* or the *Erase Selected Spectra* operation is chosen, the next screen brought up is a sub-menu that is used for searching the catalog of stored spectra, as shown in Figure 23. As you can see, this menu is shown in gray rather than color, indicating that it is a sub-menu of another menu operation.

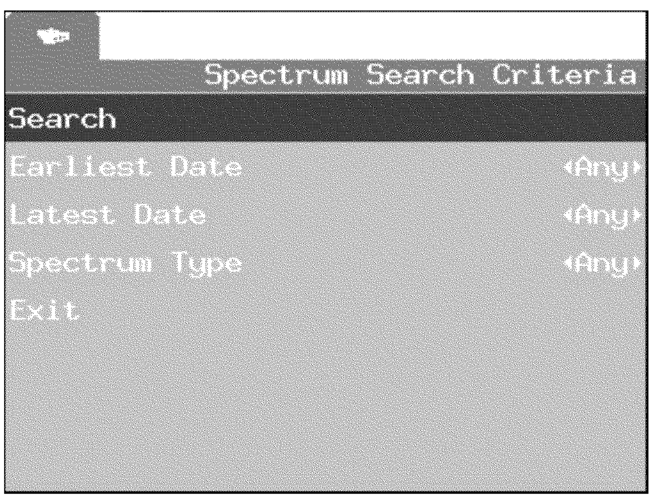


Figure 23 - *Spectrum Search Criteria* Submenu

In this menu, you can set the *Earliest Date* and *Latest Date* for the search, so that only a specific set of spectra are considered. (See Section 5.1.6 for details about the date entry.) You can also restrict the search to a single *Spectrum Type*, such as "captured alarm"or "background", or leave it open to any type. The default settings shown above will include every spectrum in the catalog.

Once you have set any search limits you want, you must highlight the *Search* item as shown in Figure 23 and press ENTER to continue to the next step, the selection of individual spectra.

The next sub-menu is shown in Figure 24. This menu gives you the opportunity to accept or reject individual spectra. This step may be less important when displaying spectra, especially if your filter is very narrow. However, when erasing spectra, you must individually go through and check mark each spectrum that you wish to erase, as a confirmation that you really wish to permanently delete that spectrum. (Note: When erasing spectra, you will not be allowed to check the currently used background spectrum.)

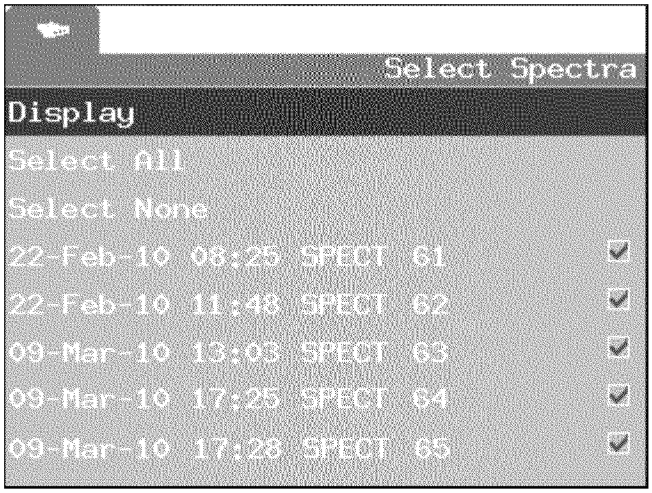


Figure 24 - *Select Spectra* Submenu

Once you have checked the relevant spectra, you must select the *Display* or *Erase* item at the very top of the menu. To quickly access this item, you may wish to go to the top of the menu by pressing MENU (if needed).

If you are erasing spectra, the process will complete and return you to the *Spectral Data* menu. However, if you are reviewing spectra, you will instead see a screen similar to the one shown in Figure 25.

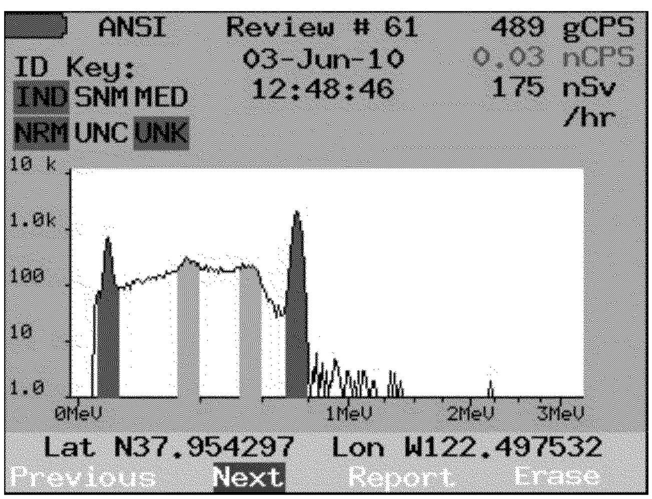


Figure 25 - Review Mode Screen

This display allows you to review a particular spectrum. The soft keys **Previous** and **Next** will take you through the list of spectra you selected in the previous step (Figure 24). The **Report** soft key will let you see the detailed analysis of the data, and **Erase** will allow you to delete the spectrum and the analysis report.

When reviewing a spectrum, pressing the Up arrow key allows you to place a cursor on the spectrum. The Left and Right arrow keys then allow lateral placement of the cursor to readout energy and count data in the information area just below the spectrum.

5.2.2 Field Settings

Figure 26 shows the **User** *Field Settings* menu. This menu shown is intended to put all the most frequently used items at the user's fingertips.

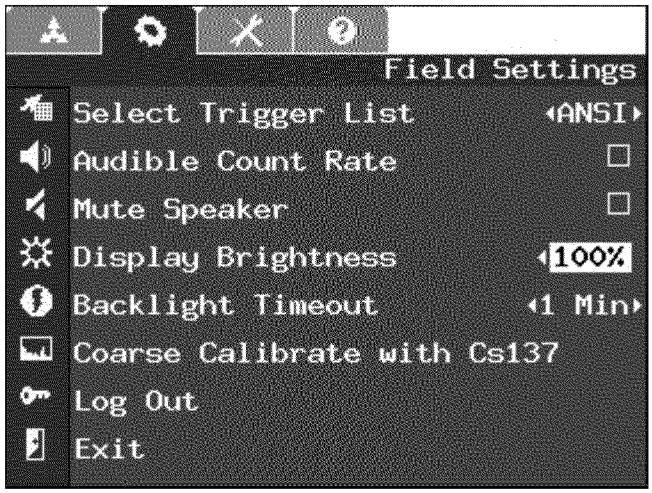


Figure 26 - User's *Field Settings* Menu

- Select Trigger List

  The "Trigger List" is the list of all of the nuclides that are currently enabled for real-time detection and analysis when you are in Search Mode. Knowing the kind of nuclides for which you normally search will help reduce false identifications. There are five standard lists included, although your **Administrator** may choose to have different options available. These are:

  ANSI – standard nuclides from ANSI N42.34.

  SNM – list of special nuclear materials, normally a subset of ANSI list

  IND – list of industrial isotopes, normally a subset of ANSI list

  MED – list of medical isotopes, normally a subset of ANSI list

  BNC – list of common check sources and "laboratory" isotopes

  In addition to changing lists with Left and Right, pressing Enter will display the contents of the currently selected list. You can press Enter again to return to the menu.

- Audible Count Rate

  This option simply turns on and off the audible clicks that indicate the count rate. It is important to note that if the speaker is muted (see next item), you will not hear these clicks unless you are using headphones. Generally, you should hear the clicks as soon as you check the check-box.

- Mute Speaker

  This option turns on and off the internal SAM 940 speaker– when the box is *checked*, the speaker is *off*. No matter how this option is set, the headphone will continue to operate, allowing inconspicuous audio monitoring.

- Display Brightness

  This setting increases or decreases the brightness of the display "backlight." Because the display backlight is one of the largest consumers of battery power, changes to this setting can significantly impact your battery life. It is recommended that this be set to the lowest setting that still gives a comfortably readable display.

- Backlight Timeout

  You can set the timeout for the display backlight. The backlight will turn off if there is no activity for this amount of time. To turn the backlight on again, press any key. Again, because backlight use increases the battery discharge rate, using small timeout settings will give longer useful battery life.

- Coarse Calibrate with Cs137

  This operation performs a manual calibration, as described in Section 4.1 starting on page 20.

- Log Out

  This operation takes you back to the *Login* screen. You can then log in as **User** or **Administrator**, as described in Section 1.7 on page 6.

- Exit

  This selection takes you back to the *Search Mode* screen as described in Section 3.2 on page 13.

5.2.3 Configuration

The **User** configuration menu is very short, and contains only a few of the items shown on the **Administrator** version of the same menu (see Section 5.3.1). The **User** version of the menu is shown in Figure 23.

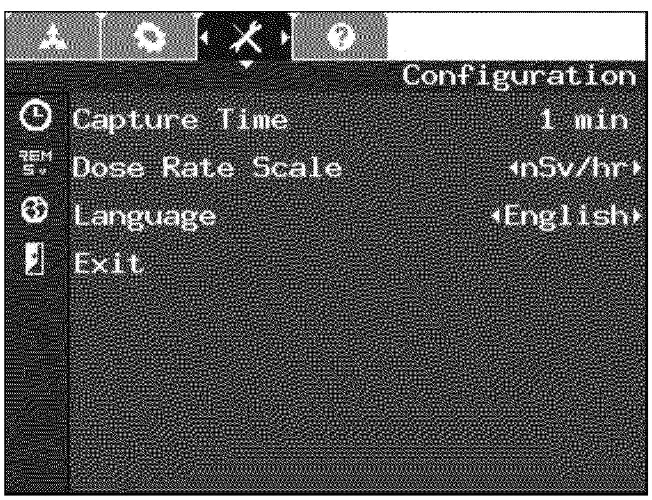


Figure 23 – User's *Configuration* Menu

- Capture Time

  The Capture Time setting determines the default run time for the **Identify** operation. You can either change the default time here, or increase or decrease the time from the **Identify** screen itself.

- Dose Rate Scale

  This setting changes the preference for the display of dose rates. There are four options: µREM/hour, mREM/hour, nSieverts/hour, and µSieverts/hour; these are abbreviated on-screen. All dose rates are stored internally in the same units, so this has no effect on stored data, only on the way it appears on the display. When viewing the full **Administrator** menu, you will see that the dose level settings also change to match the currently selected unit value.

- Language

  This allows you to select among different user interface languages. Full support for languages other than English may require an upgrade package – consult factory for details.

- Exit

  This selection takes you back to the *Search Mode* screen as described in Section 3.2 on page 13

5.2.4 Help Menu

The *Help* menu provides in-system help for many of the features described in this manual. Each item in the menu is a separate help topic that can be read using a scrolling help viewer. The first page of the *Help* menu is shown in Figure 24.

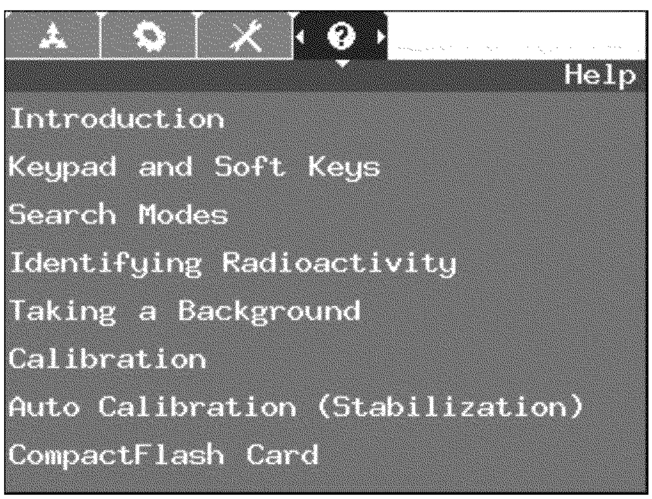


Figure 24 - *Help* Menu

To access any help item, highlight that item and press ENTER. If a scroll-bar is shown on the right, you may wish to scroll through the text using the UP and DOWN arrow keys. When you are done reading the help item, press ENTER again to return to the menu.

5.3 Administrator Menus

The **Administrator** has not only additional menus, but additional menu items on the *Configuration* menu. These allow the system to be customized for a particular application, while still providing only the most frequently used items to the **User**.

5.3.1 Configuration (Extra Items)

The **Administrator** *Configuration* menu is shown in Figure 25. The last three items are identical in function to those found for the **User**, as documented in Section 5.2.3. The additional items are described below.

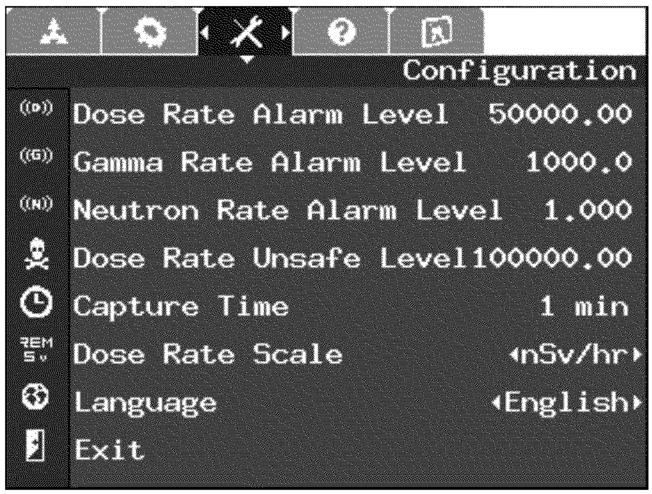


Figure 25 - Administrator's *Configuration* Menu

- Dose Rate Alarm Level

  This setting determines the dose rate required to set off the dose rate warning alarm. This is specified in the units given by the *Dose Rate Scale* further down in the menu. The system will flash the screen and sound an audio alert when this level is reached.

- Gamma Rate Alarm Level

  This setting determines the gamma count rate (in CPS) that will set off the gamma warning alarm. Although this has some functional overlap with the dose rate alarm, there may be cases where a low energy source with a high count rate would set off this alarm but not the dose rate alarm. The system will flash the screen and sound an audio alert when this level is reached.

- Neutron Rate Alarm Level

  This setting determines the neutron count rate (in CPS) that will set off the neutron warning alarm. This is generally set much lower than the *Gamma Rate Alarm Level* because true background neutron events are quite rare. The system will flash the screen and sound an audio alert when this level is reached.

- Dose Rate Unsafe Level

  This setting determines the dose rate that will set off the personnel protection or "turnback"alarm. This is specified in the units given by the *Dose Rate Scale* further down in the menu. The system will flash the screen red and sound a distinctive audio alert when this level is reached.

5.3.2 Admin

The *Admin* menu is shown in Figure 26 and Figure 27. This menu contains utilities for setting up the instrument and changing the protections of the various modes.

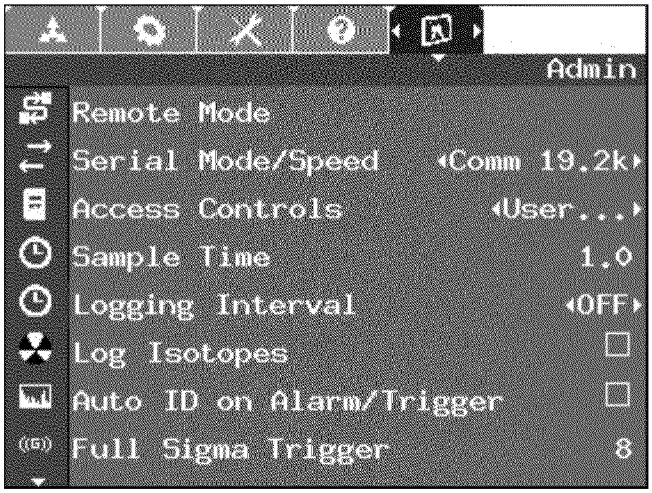


Figure 26 - *Admin* Menu, Part 1

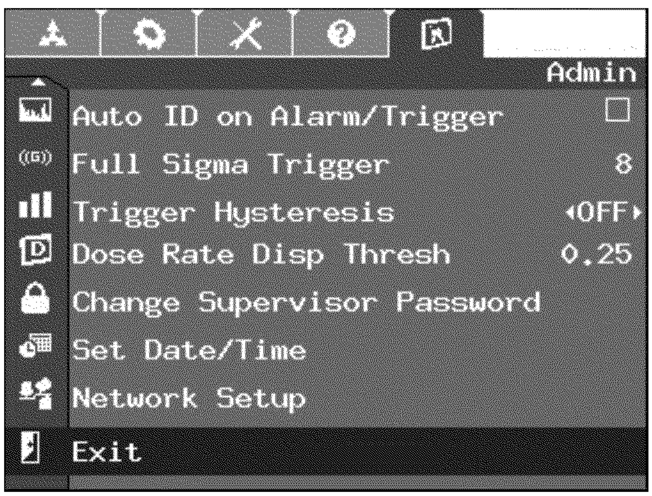


Figure 277 - *Admin* Menu, Part 2

- Remote Mode

  This operation puts the unit into a remote communications mode, as described in Section 2.4 starting on page 9.

- Serial Mode/Speed

  This operation selects the serial transfer rate for Remote Mode. The choices are Comm 115k and Comm 19.2k for RS232 and Ethernet in general; Strm 115k for remote update with Quantum™ Software, and NMEA for GPS streaming (this choice is only available if your SAM 940 has the GPS option installed).

- Access Controls

  This item brings up a sub-menu for the currently selected login, either *User* (as shown above) or *Admin*. The login can be selected using the LEFT or RIGHT arrow keys. The submenu is shown in Figure 288, Figure 299 and Figure 30.

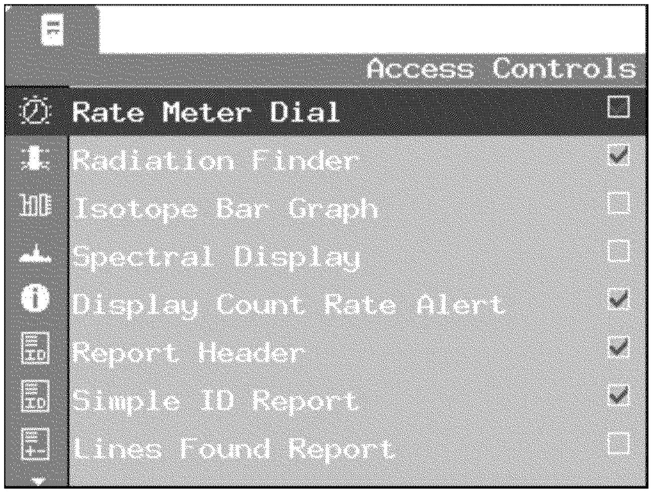


Figure 288 - *Access Controls* Submenu, Part 1

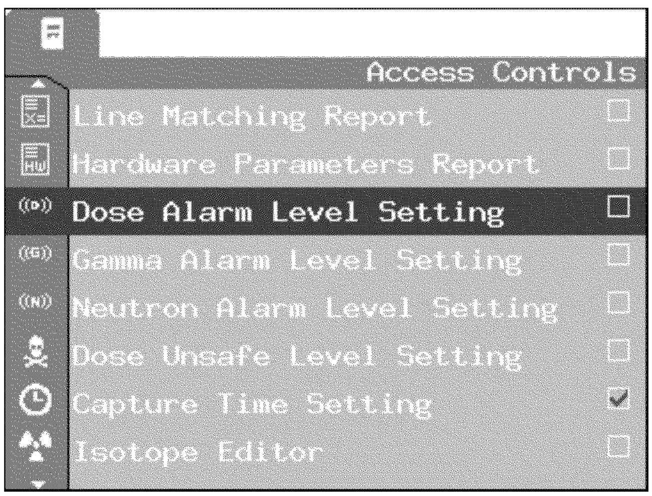


Figure 299 - *Access Controls* Submenu, Part 2

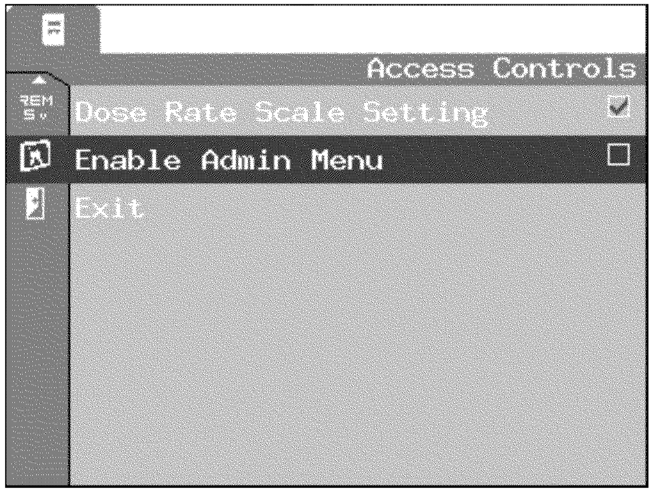


Figure 30 - *Access Controls* Submenu, Part 3

Each of the items shown corresponds to a different feature that may be either enabled or disabled for the selected login. *Rate Meter Dial* through *Spectral Display* determine which search modes are enabled. *Display Count Rate Alert*...The five *Report* items enable and disable separate sections of the on-screen report described in Section 3.5. The *Level Setting* items, *Capture Time Setting*, and *Dose Rate Scale Setting* items are features that appear in the *Configuration* menu, so that additional items may be added or removed for **User** access. As of the current firmware version, the *Isotope Editor* function is not yet supported in the SAM 940 product, and presently has no effect. *Enable Admin Menu* allows the **Administrator** to make the *Admin* menu accessible to any operator that is logged in as **User.**

- Sample Time

  The SAM 940 collects and analyzes spectra in real time. The *Sample Time* is the spectrum acquisition time, sometimes called the time slice. The recommended minimum sample acquisition time is one second; however, a 3 to 5 second setting is recommended for dose rate monitoring. Select a short sample if a quick response is required. Select a longer time if more averaging is desired or to reduce stray bars displayed in the *Bars* mode.

- Logging Interval

  This operation enables and initializes the logging of GPS coordinates into data files on the CF card. It also allows the user to select the rate at which GPS coordinates are logged. The choices are OFF, 1 sec, 2 sec, and 5 sec. Additional information can be found in the GPS Log Files section of the Addendum on page 41.

- Log Isotopes
- Auto ID on Alarm/Trigger
- Full Sigma Trigger
- Trigger Hysteresis
- Dose Rate Display Threshold

  This setting applies only to the *Bars* mode. It determines the minimum per-isotope dose rate that is required before a bar will be displayed. Once the dose rate reaches this level for one *Sample Time* period, the bar will appear. (It will then remain on the screen for up to 30 seconds, even if the level falls below the threshold again, to make the display easier to follow visually.)

- Change Supervisor Password

  The password used for the **Administrator** login (Section 1.7) may be changed by the **Administrator**. To do this, you must enter the old password first, and then enter the new password, as shown in Figure 31.

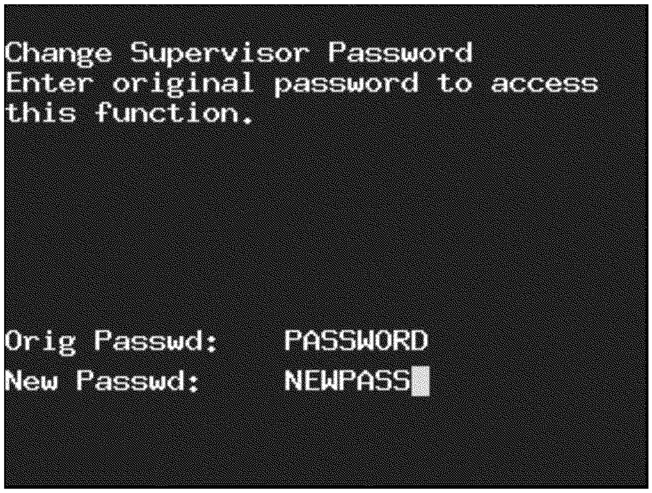


Figure 31 - Changing Password

- Set Date/Time

  Because the SAM 940 records the date and time of every spectrum collected in Universal Coordinated Time (UTC), it must not only know the date and time but also the current time zone. All of these are set from this menu item, which opens the dialog shown in Figure 302.

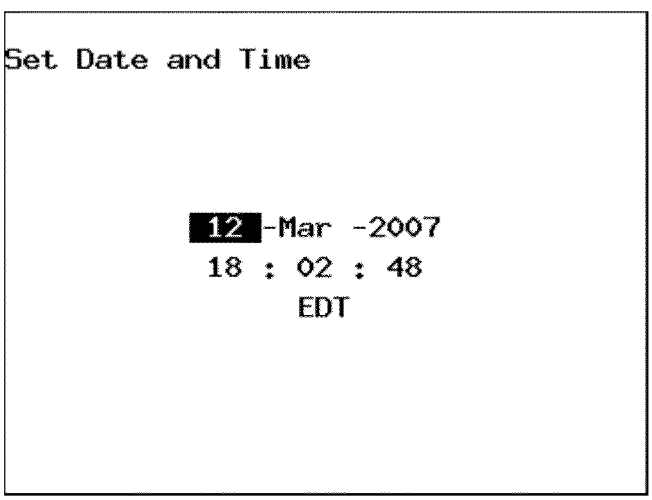


Figure 302 - Setting Date and Time

To change from one field to the next, use the LEFT and RIGHT arrows. To increase or decrease the value of a particular field, use the UP or DOWN arrows, respectively. If you need to change the time zone, it is recommended that you do this first, because the hour (and possibly minute) will be automatically updated when you make this change. Finally, press ENTER to accept the currently shown date and time.

- Network Setup

  The SAM 940 supports Ethernet communications for remote data collection. In order to establish communications between the PC and the SAM 940, the network information for the SAM 940 must be configured in the device, and then entered into the software's "Hardware Search"utility. Figure 313 shows the *Network Setup* dialog, with sample values entered. You will need to get the correct values for your own network from your network administrator.

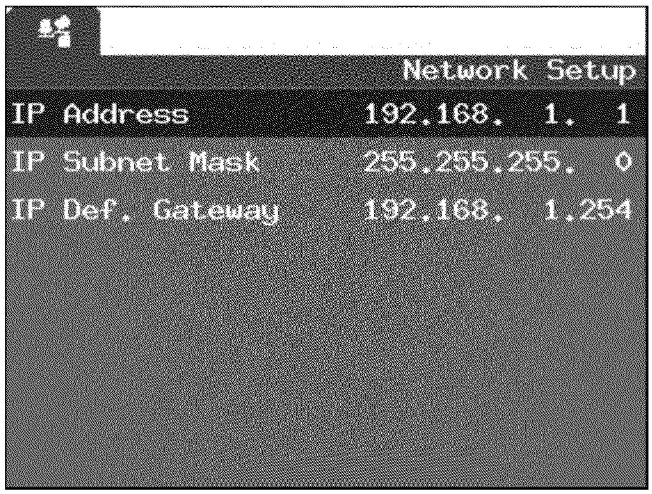


Figure 313 - Network Setup Dialog

Each of the three items (*IP Address, IP Subnet Mask,* and *IP Default Gateway*) must be highlighted in turn. By pressing ENTER, you can then edit each digit with the UP and DOWN arrows, and move between digits with the LEFT and RIGHT arrows.

5.3.3 Factory Settings

There is an additional *Factory Settings* menu that is normally only used at the factory. Under special circumstances, including at Beta test sites, this menu may be enabled, but the details of how to use this menu are beyond the scope of this document.

6 Support Programs

6.1 Factory Technical Support

6.2 Protocol Development

6.3 Vendor Enhanced Reachback Program

6.4 State or Federal Agency Support

7 Software Support

7.1 Software for first line responders

7.2 Software for advanced users

The Quantum™ software is a useful tool for advanced users seeking additional analytical capabilities for their SAM 940 spectra.

Quantum MCA provides qualitative, but not quantitative analysis. Qualitative analysis will allow analyzing for what isotopes are present, but not how much of each isotope is present. Certain features, such as background subtraction, are considered part of the quantitative analysis package and are not available in Quantum MCA.

8 Specifications

Preamplifier

Type:	Charge Sensitive
Input:	Negative Current (anode)

ADC

Type:	14-bit pipelined
Speed:	50 MHz

Pulse Processing

Type:	Digital, Trapezoidal Shaping
Peaking times:	40 ns to 5.1 μs, factory set to 1.28 μs
Gain:	Digital, 0.25x to 16x.
LLD:	0 to 100 % of full scale digitally adjustable in .006 % intervals
ULD:	0 to 100 % of full scale digitally adjustable in .006 % intervals
Zero:	-5 % to + 5 % of full scale, digitally adjustable

Spectrum Conversion

Collection Mode:	Linear – 16384 Channels
Conversion Modes:	Linear – 256, 512, 1024 Channels
	QCC – 256, 512, 1024 Channels (U.S. Patent 5,608,222)

System Controller

Processor:	PPC405 CPU at 50 MHz
Display:	320 x 240 high contrast 32000 color display with LED backlight
Controls:	7-key custom keypad
I/O:	RJ-45 Ethernet port for computer connection
	ENP3 series watertight connector for power and other functions
Clock:	Battery-backed-up clock/calendar

Power

Batteries:	Internal, 8 x 2900 mAh NiMH AA batteries
AC:	35 W, 12 V or 15 V universal AC adapter
	(depending on system revision)
Auto:	9 V fused accessory adapter

Gamma Detector

Crystal:	2"x 2" or 3 "x 3 "NaI; or 1 "x 1 "or 1.5 "x 1.5 "LaBr
Bias:	Integral HV supply from 0 – 1200 V
	Actual operating voltage calibrated to each detector
Connection:	IP67 watertight LEMO

Neutron Detector (if present)

Type:	^{6}LiI or ^{3}He
Moderator:	1 cm polypropylene
Discriminator:	Digital pulse shape and energy discrimination

9 Addendum

BNC Quick Start for Trimble ProXT GPS Receiver

Berkeley Nucleonics Corp. advises that you read and familiarize yourself with the GPS Pathfinder Pro series User Guide and Software Manual on the CD that accompanies your Trimble ProXT GPS Receiver. Please observe all safety and usage advisements contained therein. Below is a summary of steps to ensure that the ProXT is prepared to interface with the Model SAM940.

1) Install the "GPS Controller"Software program onto your PC from the Pathfinder Pro CD.

2) Turn on the ProXT according to the instructions in the GPS Pathfinder Pro series User Guide beginning on page 13.

3) Turn off the Bluetooth radio function as described in the GPS Pathfinder Pro series User Guide beginning on page 14.

4) Use a Null Modem RS232 cable to connect the ProXT to your PC as described in the GPS Pathfinder Pro series User Guide beginning on page 21.

5) Open the GPS Controller program on your PC.

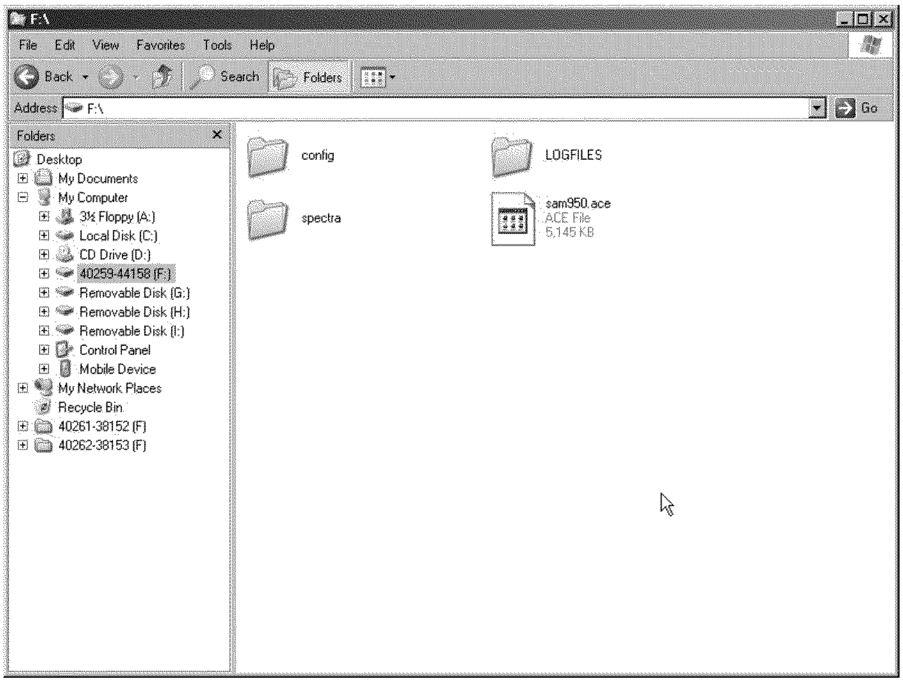
6) Use the GPS Settings menu and configure the ProXT to send GPS NMEA data via Port 1 as described in the GPS Pathfinder Pro series User Guide beginning on page 27.

7) The next time the power is cycled on the ProXT, it should power up with Bluetooth disabled and GPS NMEA data streaming from Port 1.

8) Refer to the SAM940 Instruction Manual page 10 to connect the ProXT to the SAM.

GPS Log Files

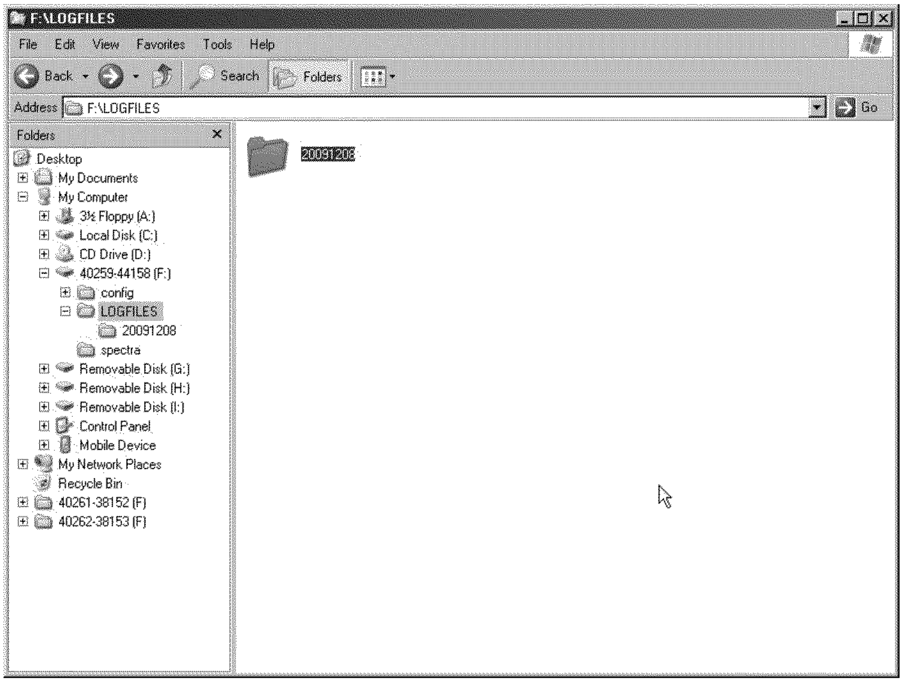
The SAM 940 currently stores all of its configurable information on the compact flash card located behind the LCD screen. This includes the firmware, calibration data, stored spectra, libraries, and general configuration settings. Users will need a compact f lash card reader to access this data with a computer.



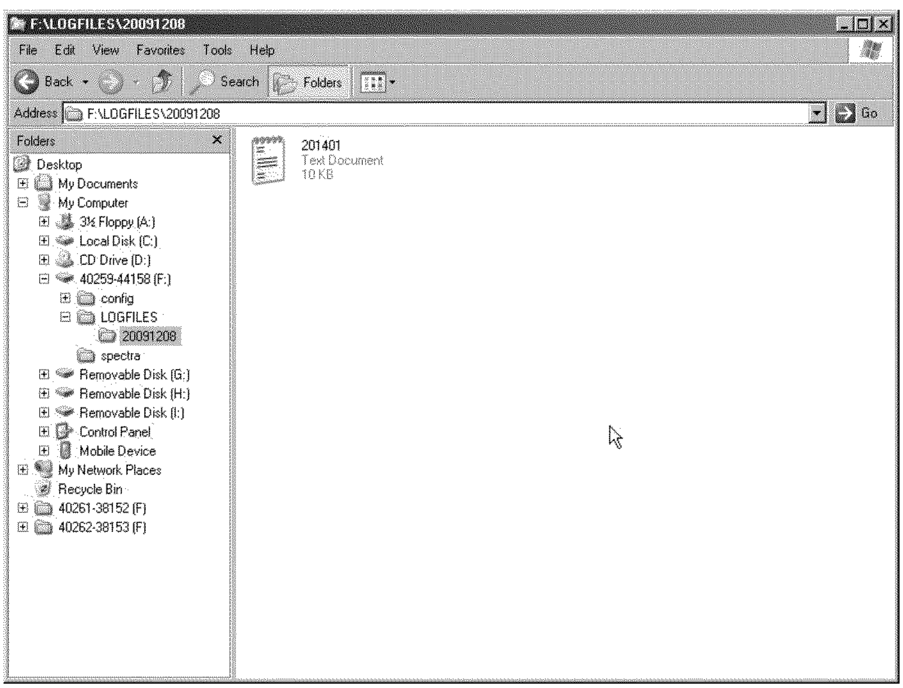
Each CF card will have 4 items as shown above:

1) **SAM950.ACE** – Compressed Firmware driver files.
2) **Config folder** – Configuration settings, includes libraries and user info.
3) **Spectra folder** – Stored spectra (.N42 files are spectra located inside spectra folder.)
4) **LOGFILES folder** – GPS Log Files

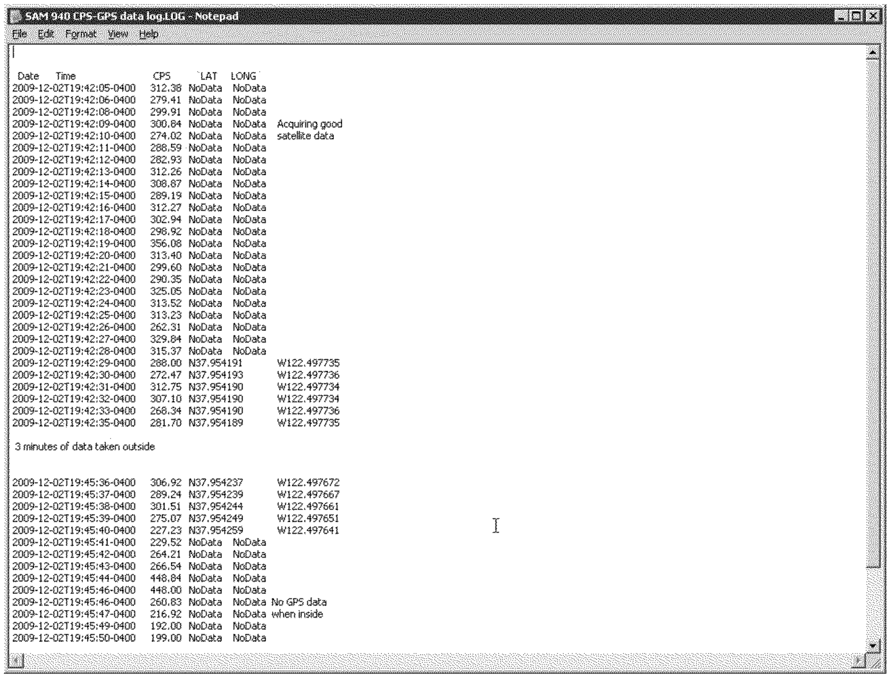
LOGFILES Folder Contents



If the Logging Interval is active when the SAM powers up, a new folder will be created in the LOGFILES folder on the CF card. The new folder will be titled with the date that the SAM was powered up.



Subsequently, a new Log File will be created in the dated folder. The new file will be titled with the time that the SAM begins receiving data from the GPS receiver.



SAM 940 CPS-GPS data log.LOG - Notepad

File Edit Format View Help

```
 Date   Time                     CPS     LAT    LONG
2009-12-02T19:42:05-0400  312.38  NoData  NoData
2009-12-02T19:42:06-0400  279.41  NoData  NoData
2009-12-02T19:42:08-0400  299.91  NoData  NoData
2009-12-02T19:42:09-0400  300.84  NoData  NoData   Acquiring good
2009-12-02T19:42:10-0400  274.02  NoData  NoData   satellite data
2009-12-02T19:42:11-0400  288.59  NoData  NoData
2009-12-02T19:42:12-0400  282.93  NoData  NoData
2009-12-02T19:42:13-0400  312.26  NoData  NoData
2009-12-02T19:42:14-0400  308.87  NoData  NoData
2009-12-02T19:42:15-0400  289.19  NoData  NoData
2009-12-02T19:42:16-0400  312.27  NoData  NoData
2009-12-02T19:42:17-0400  302.94  NoData  NoData
2009-12-02T19:42:18-0400  298.92  NoData  NoData
2009-12-02T19:42:19-0400  356.08  NoData  NoData
2009-12-02T19:42:20-0400  313.40  NoData  NoData
2009-12-02T19:42:21-0400  299.60  NoData  NoData
2009-12-02T19:42:22-0400  290.35  NoData  NoData
2009-12-02T19:42:23-0400  325.05  NoData  NoData
2009-12-02T19:42:24-0400  313.52  NoData  NoData
2009-12-02T19:42:25-0400  313.23  NoData  NoData
2009-12-02T19:42:26-0400  262.31  NoData  NoData
2009-12-02T19:42:27-0400  329.84  NoData  NoData
2009-12-02T19:42:28-0400  315.37  NoData  NoData
2009-12-02T19:42:29-0400  288.00  N37.954191        W122.497735
2009-12-02T19:42:30-0400  272.47  N37.954193        W122.497736
2009-12-02T19:42:31-0400  312.75  N37.954190        W122.497734
2009-12-02T19:42:32-0400  307.10  N37.954190        W122.497734
2009-12-02T19:42:33-0400  268.34  N37.954190        W122.497736
2009-12-02T19:42:35-0400  281.70  N37.954189        W122.497735

 3 minutes of data taken outside


2009-12-02T19:45:36-0400  306.92  N37.954237        W122.497672
2009-12-02T19:45:37-0400  289.24  N37.954239        W122.497667
2009-12-02T19:45:38-0400  301.51  N37.954244        W122.497661
2009-12-02T19:45:39-0400  275.07  N37.954249        W122.497651
2009-12-02T19:45:40-0400  227.23  N37.954259        W122.497641
2009-12-02T19:45:41-0400  229.52  NoData  NoData
2009-12-02T19:45:42-0400  264.21  NoData  NoData
2009-12-02T19:45:43-0400  266.54  NoData  NoData
2009-12-02T19:45:44-0400  448.84  NoData  NoData
2009-12-02T19:45:46-0400  448.00  NoData  NoData
2009-12-02T19:45:46-0400  260.83  NoData  NoData No GPS data
2009-12-02T19:45:47-0400  216.92  NoData  NoData when inside
2009-12-02T19:45:49-0400  192.00  NoData  NoData
2009-12-02T19:45:50-0400  199.00  NoData  NoData
```

The Log File will capture Date, Time, CPS, Lat., and Long. data. An annotated example is shown above. To restart a new log file, either (a) turn the SAM power off and back on, or (b) select a different logging interval in the menu and then change it back. For example if you change the logging interval from 2 seconds to 1 second and then back to 2 seconds, you might get a (brief) new log file at the 1 second rate, but a new log file at the 2 second interval will be created and titled with the time that the new file begins.

Higher level host software on your PC can parse the data fields within the log file for data collection.